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USAAEFA

USAAEFA PROJECT NO. 82-18

PRELIMINARY AIRWORTHINESS EVALUATION OF THE RUTAN AIRCRAFT FACTORY (RAF), INC. LONG-EZ AIRPLANE

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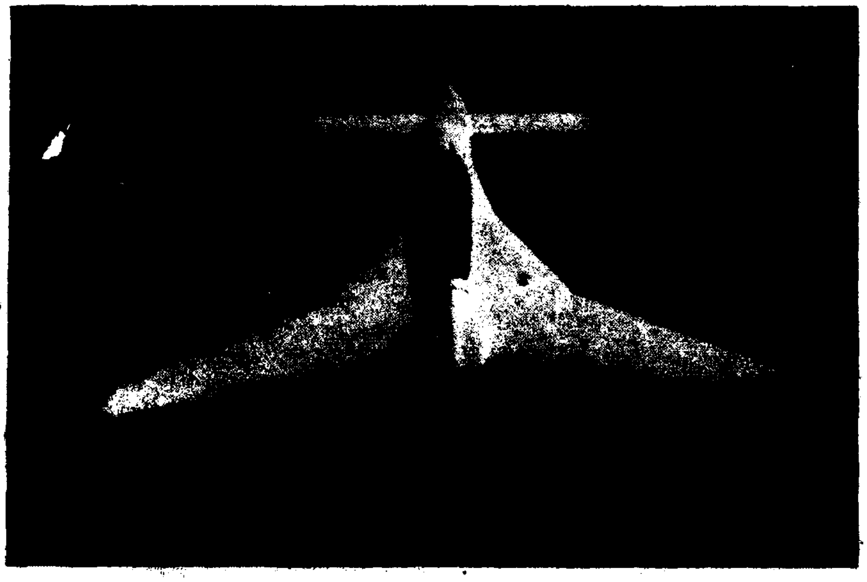

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UNITED STATES ARMY AVIATION ENGINEERING FLIGHT ACTIVITY
EDWARDS AIR FORCE BASE, CALIFORNIA 93523

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The United States Army Aviation Engineering Flight Activity conducted a Preliminary Airworthiness Evaluation of the Rutan Aircraft Factory, Inc. designed LONG-EZ airplane ~~from 14 January through 1 April 1983~~ at Edwards Air Force Base, California. During the test program 34 flights were conducted for a total of 32.0 hours, of which 24.5 were productive. The objectives of the evaluation were to assess the performance and handling qualities of the LONG-EZ so that the US Army Aviation Research and Development Command could issue (over)

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an airworthiness release ~~to the 9th Infantry Division~~ for concept feasibility evaluation of the aircraft. The test aircraft ~~(S/N 82-1240; N1253)~~ exhibited excellent potential for the light observation/reconnaisance mission and is satisfactory for the intended concept feasibility evaluation. The high availability and minimal maintenance down time due to ease of repair of composite structures during flight testing of the LONG-EZ were noteworthy. One deficiency and fifteen shortcomings were identified. The loss of directional control due to single point brake failure during take-off/landing and ground handling was identified as a deficiency and is a safety-of-flight hazard. The major shortcomings affecting mission versatility and pilot effectiveness were: decrease in engine power during low g maneuvers; limited directional control; excessive throttle freeplay; limited longitudinal trimmability; and inaccessability of the lateral trim system. The deficiency should be corrected if development continues. The shortcomings should be corrected prior to production.

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DRSAV-E

SUBJECT: Directorate for Engineering Position on the Final Report of USAAEFA Project No. 82-18, Preliminary Airworthiness Evaluation of the Rutan Aircraft Factory (RAF), Inc. LONG-EZ Airplane

SEE DISTRIBUTION

1. The purpose of this letter is to establish the Directorate for Engineering position on the subject report. The LONG-EZ airplane tested by the US Army Aviation Engineering Flight Activity (USAAEFA) is a home built, Experimental class aircraft certified under Federal Aviation Regulation (FAR), Part 21. The airplane was built by members of the 9th Infantry Division (9th ID), Fort Lewis, Washington for the purpose of an operational evaluation. Since the airplane did not have an Airworthiness approval per the requirements of AR 70-62, it was necessary to implement an Airworthiness Qualification Program (AQP). The AQP included a review of all contractor data, static and dynamic tests of the complete airplane and an experimental flight test program by USAAEFA. Based on the results of the flight test, an envelope was developed and an Airworthiness Release issued to the 9th ID for the operational evaluation.

2. This Directorate agrees with the conclusions stated in this report. Although one deficiency and 15 shortcomings were identified there is no intent to correct them at this time since there are no plans to operationally deploy or type classify the airplane. If the decision is made to deploy or classify, then the deficiency must be corrected and the shortcomings eliminated if feasible. When operated within the restrictions and limitations of the Airworthiness Release the LONG-EZ airplane can be safely flown for the operational evaluation. Paragraph 67 of the report states there were three requirements of specification MIL-F-8785C which were not met. Since there was no requirement for evaluating against MIL-F-8785C the specification was only used as a guide for the purposes of testing.

3. The USAAEFA evaluation identified numerous safety-of-flight and construction deficiencies as reported which necessitated correction prior to flight. These type Deficiences can be expected in a home built airplane because of a lack of quality assurance control during construction. Any future LONG-EZ airplanes to be constructed and used for future operational testing will require a maintenance inspection, and limited flight evaluation by USAAEFA to insure there are no significant adverse variations in construction and flying qualities.

DRSAV-E
SUBJECT: Directorate for Engineering Position on the final Report of USAAEFA Project No. 82-18, Preliminary Airworthiness Evaluation of the Rutan Aircraft Factory (RAF), Inc. LONG-EZ Airplane

The requirement to conduct additional static and dynamic testing of the airplane is not necessary since the structural adequacy of the basic LONG-EZ design, when operated within the Airworthiness Release restrictions and limitations, is satisfactory. It is essential to understand that the LONG-EZ was not designed to military requirements and that any decision to deploy operationally should consider design changes for improved mission suitability. As a minimum the following need to be addressed:

a. Emergency egress. The inherent configuration of the aircraft may result in the crew being trapped inside the canopy if the aircraft is flipped over. Canopy breakaway/removal needs to be addressed.

b. Field of view. May be inadequate because of limited vision forward and down.

c. Crew seating. A means of adjusting the crew's seating, perhaps with pads, should be addressed to provide any size of crew the highest possible eye position.

d. Nose gear. Home builders have experienced weakness and occasional collapse of the nose gear on early versions of the LONG-EZ design. If operation is contemplated from non-paved surfaces, increased gear ruggedness may be required.

e. Paint. The Army specifies olive drab and flat black for its helicopter exterior and interior surfaces. Should the LONG-EZ missions require such finishes, the problems/limitation of the structural composite materials may need to be addressed from the standpoint of solar heat degradation.

f. Storage. If potential missions require the crew to utilize charts/hardware, the size/proportion of the crew station should be evaluated for adequacy.

4. The USAAEFA report of the LONG-EZ PAE is an outstanding, fully comprehensive documentation of a well conducted experimental flight test and evaluation effort of a home built aircraft not designed to military standards. The excellent effort by USAAEFA provided the basis for issuance of an Airworthiness Release to the operational tester for operation with a well defined safe envelope.

FOR THE COMMANDER:

Ronald E. Gormont

RONALD E. GORMONT
Acting Director of Engineering

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INTRODUCTION

BACKGROUND

1. The LONG-EZ is a small, lightweight airplane designed by the Rutan Aircraft Factory (RAF), Inc. The airplane is a home-built, experimental class aircraft certified under Federal Air Regulation (FAR) Part 21 (ref 1, app A) of the Federal Aviation Administration (FAA). It is intended to be built according to the LONG-EZ manufacturing manual by private construction with materials and prefabricated parts obtained from commercial sources. The Army's interest in the aircraft is exploratory for missions not yet completely defined. Two airplanes have been assembled by the 9th Infantry Division (9th ID) at Fort Lewis, Washington. The US Army Aviation Engineering Flight Activity (USAAEFA) was tasked by the US Army Aviation Research and Development Command (AVRADCOM) (ref 2) to conduct a Preliminary Airworthiness Evaluation (PAE) on the performance and handling qualities of the LONG-EZ aircraft in a clean configuration. The two aircraft will be evaluated in a wide range of mission configurations, to be defined, during subsequent flight test programs.

TEST OBJECTIVES

2. The objectives of the evaluation were to obtain quantitative and qualitative flight test data on performance and flying qualities necessary for AVRADCOM to issue an airworthiness release for the 9th ID to evaluate the LONG-EZ.

DESCRIPTION

3. The test vehicle, Serial Number 82-1240 (N1253), designed by RAF and constructed by the 9th ID according to the LONG-EZ manufacturing plans is a two place, tandem seat, home-built, experimental class aircraft with a maximum gross weight of 1325 pounds. Unique features include composite construction, a nose mounted canard for pitch control, and a mid-wing high aspect ratio Eppler swept airfoil with tip mounted winglets. The airplane also features tricycle landing gear (with a retractable nose wheel) and a landing airbrake (belly mounted "speed brake"). Propulsion is provided by a rear mounted Lycoming O-235-L2C reciprocating engine rated at 118 brake horsepower on a sea level standard day and a fixed pitch Ted Hendrickson manufactured wooden propeller. Further description of the aircraft is presented in appendix B and a more detailed description of the LONG-EZ is contained in the owner's manual (ref 3, app A).

TEST SCOPE

4. A limited performance and handling qualities evaluation of the LONG-EZ was conducted in a three phase program at Edwards Air Force Base, California (2302 foot field elevation) as prescribed by the airworthiness release (ref 4, app A). The evaluation was conducted from 14 January through 1 April 1983. Phase I of the program consisted of static structural tests of the wings and control systems and determination of frequencies and modal damping of all airfoil surfaces. These tests were conducted by AVRADCOM with USAAEFA assistance utilizing the National Aeronautics Space Administration (NASA) Dryden Flight Research Facility, Structural Laboratory. Phase II entailed initial flight envelope expansion and inflight flutter evaluation as recommended by RAF (ref 3), followed by quantitative and qualitative flight testing in Phase III. During the test program 34 flights were conducted for a total of 32.0 hours, of which 24.5 were productive. A limited number of flights were accomplished in turbulent air conditions to evaluate the stability and control of the aircraft under representative operating conditions. Performance capabilities and handling qualities characteristics were compared with military specification criteria (ref 5), and RAF obtained flight test data (ref 3). Flight restrictions and operating limitations contained in the airworthiness release issued by AVRADCOM (ref 6, app A) were observed during the evaluation. The airplane configurations are presented in table 1 with the test conditions shown in tables 2 and 3.

TEST METHODOLOGY

5. Established flight test techniques and data reduction procedures were used during this test program (refs 7 and 8, app A). The test methods are described briefly in the Results and Discussion section of this report. Flight test data were hand-recorded from test instrumentation on the pilot panel and automatically recorded on ground based magnetic tape via telemetry. A list of the test instrumentation is contained in appendix C. Test techniques (other than the standard techniques described in appropriate references), weight and balance, and data reduction techniques are contained in appendix D. A Handling Qualities Rating Scale (HQRS) (fig. 1, app D) was used to augment pilot comments relative to the aircraft handling qualities. A Vibration Rating Scale (VRS) (fig. 2, app D) was used to augment pilot comments relative to vehicle vibration levels. Deficiencies and shortcomings are in accordance with the definitions presented in appendix D.

Table 1. Airplane Configurations

Configuration	Nose Gear Position	Landing Airbrake Position	Power Setting
Takeoff (TO)	down	up	MCP[1]
Climb (CL)	up	up	MCP
Cruise (CR)	up	up	PLF[2]
Power Approach (PA)	up	down	PNA[3]
Landing (L)	down	down	IDLE-MCP
Glide (G)	up	up	OFF

NOTES:

[1]Maximum continuous power: Maximum brake horsepower (BHP) available, (limited to 118 BHP at 2800 RPM, propeller speed, sea level standard day, full rich mixture).
[2]Power for level flight: BHP required to maintain level flight, peak exhaust gas temperature (EGT) mixture.
[3]Power for normal approach: BHP required to maintain 3-degree glide angle.

Table 2. Performance Test Conditions

Test	Gross Weight (lb)	Conditions			
		Longitudinal CG Location[1] (in.)	Density Altitude (ft)	Trim Calibrated Airspeed (kt)	Configuration
Airspeed Calibration	1250	100.4	4340	87 - 147	TO, CR, CL PA, L
Level Flight Performance	1210 1260 1310	98.0 97.8 97.4	3880 7890 12,800	64 - 132 69 - 132 66 - 112	CR
Glide Performance	1320 1250	97.1 103.7	9660 8700	76 - 127	G,L
Takeoff Performance	1320	97.4	2300	75 - 82	TO
Landing Performance	1320	97.4	2300	76 - 86	L
Stall Characteristics	1200 1220 1310 1310	98.2 103.6 97.2 103.9	8300 9000 8590 8180	64 - 90	TO, CL, CR PA, L
Engine Cooling	1250	100	Field[2] to 10,000	82, 91	CL, PA

NOTE:

[1]Center of gravity (CG) range - FS 97 to 104
[2]Field elevation at Edwards AFB, CA: 2302 MSL

Table 3. Handling Qualities Test Conditions

Test	Conditions				
	Gross[1] Weight (lb)	Longitudinal CG Location[2] (in.)	Density Altitude (ft)	Trim Calibrated Airspeed (kt)	Configuration
Control Positions in Trimmed Forward Flight	1220 1270 1310	98.0 97.8 97.4	3820 7400 12140	68 - 148	CL, CR, PA
Static Longitudinal Stability	1290 1260	97.3 103.7	7500	138	CL, CR, L
Static Lateral-Directional Stability	1260	103.6	7770	88, 130, 168	CL, CR, L
Dynamic Stability	1210	103.8	12,000	87 - 128	CR
Roll Control Effectiveness	1250	103.8	7500	123	CR
Manuevering Stability	1250 1240	103.7 98.4	7500	123 - 170	CR
Ground Handling Characteristics	1300	101.3	Field[3]	0 - 35	TO, L
Low-Speed Taxi	1320	101.1	Field	5 - 35	TO, L
High-Speed Taxi	1300	101.4	Field	35 - 55	TO, L
Structural Dynamics	1190 1250 1320	97 100 104	10,000	130 - 190	TO, CL, CR

NOTE:
[1]Maximum gross weight: 1325 lb
[2]Center of gravity (CG) range - FS 97 to 104
[3]Field elevation Edwards AFB: 2302 MSL

RESULTS AND DISCUSSION

GENERAL

6. Performance, handling qualities, and envelope expansion of the LONG-EZ aircraft were evaluated under the conditions and configurations listed in tables 1 through 3. The test aircraft (S/N 82-1240) was evaluated against the RAF owner's manual, and military specification MIL-F-8785C. The test aircraft exhibited excellent light observation/reconnaisance capability with potential for satisfactory accomplishment of the concept feasibility evaluation; however, the airplane as evaluated was not sufficiently developed for operational deployment. There was one deficiency and fifteen shortcomings identified. The potential loss of directional control due to single point brake failure during takeoff/landing and ground handling was identified as a deficiency and is considered a safety-of-flight hazard. The major shortcomings affecting mission versatility and pilot effectiveness were: loss of engine performance during low g maneuvering; limited directional control; excessive throttle freeplay; limited longitudinal trimmability; and inaccessability of the lateral trim system. The deficiency should be corrected if development continues. The shortcomings should be corrected prior to production.

PERFORMANCE

General

7. The performance capabilities of the LONG-EZ airplane were evaluated to provide data for comparison with and as a supplement to the owner's manual. Emphasis was on operation at the maximum gross weight of 1325 pounds and at the forward center of gravity (cg) limit, fuselage station (FS) 97.0. Performance capabilities were compared to those reported for the LONG-EZ in the owner's manual. Specification engine data required for performance calculations were obtained from the detail specification for the Lycoming O-235 L2C engine (ref 9, app A). Engine installation losses were not determined. Test conditions are outlined in table 2 and data analysis techniques are contained in appendix D.

Takeoff Performance

8. Takeoff tests were performed at the conditions listed in table 2. Takeoffs were conducted by aligning the aircraft on centerline of the runway with the nose wheel straight. Full power was applied prior to releasing the brakes. Full aft longitudinal control was applied during the takeoff roll at least 20 knots indicated airspeed (KIAS) below rotation speed. Once rotation was achieved, longitudinal control was adjusted

to maintain the canard upper surface level on the horizon (approximately 12° of pitch) until attaining predetermined liftoff and climb airspeeds. During the initial portion of the takeoff roll (below 35 KIAS), considerable braking was required to maintain heading, which increased the takeoff roll. The nose wheel began to bounce on the runway at about 53 KIAS. Minimum rotation airspeed was at 60 KIAS with minimum liftoff airspeed at 64 KIAS. Control power is not available to effect an earlier rotation or liftoff for heavy weight forward cg configurations. Pitch attitudes were approximately 12 degrees during takeoff and were not uncomfortable to the pilot. Climb out airspeeds were easy to maintain except that immediately after takeoff, the indicated airspeed abruptly increased 3 to 4 knots, but was not a problem. The best takeoff performance was obtained using a rotation speed of 60 KIAS, liftoff at 64 KIAS, and climb at 66 KIAS. Control at these airspeeds was adequate to maintain desired flight path, and the attitudes were not uncomfortable. Takeoff performance qualitatively compared favorably with the data presented in the owner's manual.

Level Flight Performance

9. Level flight performance was evaluated at the conditions shown in table 2 to determine maximum level flight airspeed (V_H) at maximum continuous power, design cruising airspeed (V_{CR}) at 75% of maximum continuous power, and best range and endurance airspeeds. The zero thrust glide test method was used to obtain the baseline drag polar for the aircraft. The aircraft was stabilized and trimmed at incremental airspeeds in a descent with the engine and propeller stopped. For level flight performance testing, the constant pressure altitude technique was used for the determination of power required as a function of airspeed. The aircraft was stabilized and trimmed at incremental airspeeds from V_H to 1.1 stall speed (V_S). The results of these tests are presented in figures 1 through 6, appendix E.

10. Test results indicate the maximum airspeed in level flight at a gross weight of 1220 pounds at 3780 feet pressure altitude and standard day using maximum power available was 156 knots true airspeed (KTAS). The maximum range airspeed was 100 KTAS and the endurance airspeed was 72 KTAS. These results agree with data presented in the owner's manual.

Stall Performance

11. Stall characteristics were evaluated at the conditions and aircraft configurations listed in table 2. For the 1g stalls at an aft cg loading, the aircraft was trimmed at $1.2V_s$. For forward

cg loadings, the trim was full aft for a minimum trimmable airspeed of approximately 76 knots indicated airspeed (KIAS) ($1.4V_s$). Airspeed was decreased at approximately 1 knot per second until achieving a stall. Typical time histories of the stall characteristics are presented in figures 7 through 13, appendix E. Table 4 and figure 1 show stall speeds for the various aircraft configurations and loadings. Control forces were light during the approach to the stall with very little lateral or directional control to keep the aircraft straight and level. There was essentially no stall warning. The canard stall was defined by a docile pitch break, or pitch oscillation, or full aft longitudinal control. Deep stall reactions were characterized by a gentle nose drop, and the aircraft entered a mild longitudinal oscillation with about a 10-second period and airspeed variations of 6 to 8 KIAS. With the longitudinal control full aft there was no tendency for the aircraft to depart controlled flight. There were almost no lateral or directional control input requirements to maintain a desired flight path. Recovery was accomplished by release of aft longitudinal control pressure and addition of power (except for climb configuration). The aircraft immediately returned to level flight. The mild stall characteristics, ease of recovery, and mild post-stall reactions give the pilot increased confidence in his ability to operate the aircraft in the low airspeed regime. The 1g stall characteristics of the LONG-EZ aircraft are satisfactory.

12. The LONG-EZ has no stall warning. While the stall itself is mild, if a stall occurs during the landing flair, aircraft damage could result. In the LONG-EZ, the pilot is seated close to the ground in comparison to other aircraft. This causes a tendency for a high landing flair. The LONG-EZ stall characteristics failed to meet the requirements of paragraph 3.4.2.1.1 of MIL-F-8785C: The absence of the stall warning is a shortcoming. The following CAUTION should be included in the aircraft operating instructions.

CAUTION

Full stall landings should be avoided due to lack of stall warning.

13. Accelerated stalls were conducted using constant bank-angle turns (45° and 60°) and applying aft longitudinal control to establish a 2-knots/sec deceleration until stall occurred. There was no stall warning. The approach to stalls and post-stall reactions were mild and required almost no lateral or directional inputs to maintain roll attitude. Longitudinal

Table 4. Stall Performance

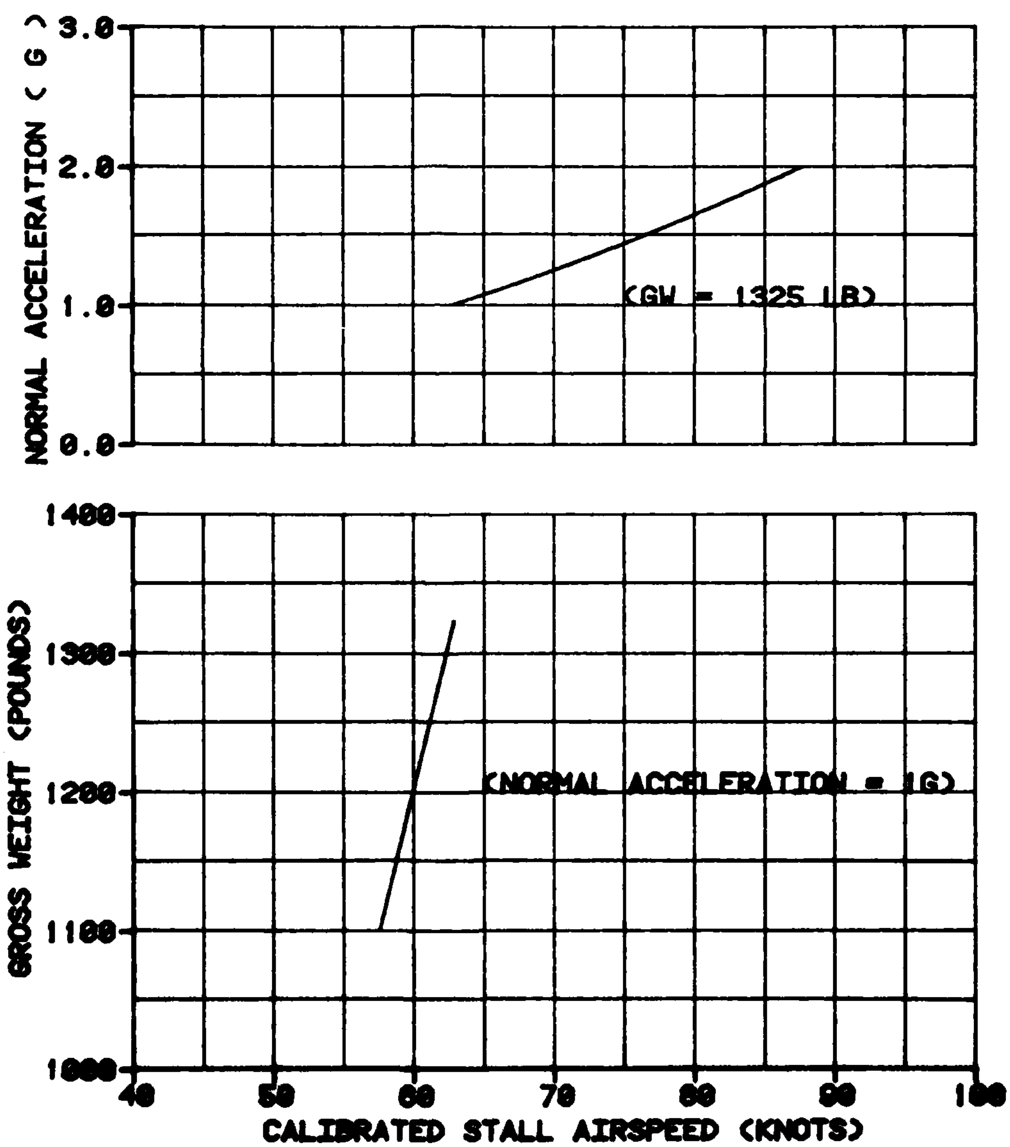
Configuration	Gross Weight (lb)	Center -of- Gravity (FS)	Calibrated Stall Airspeed (knots)				
			Wings Level	Left 45 Degree Bank	Right 45 Degree Bank	Left 60 Degree Bank	Right 60 Degree Bank
Takeoff	1200	98.2	60	68	70	78	77
Climb	1200	98.2	60	65	68	81	78
Cruise	1200	98.2	60	—[1]	—	—	—
Power Approach	1200	98.2	60	—	—	—	—
Landing	1200	98.2	60	70	70	79	75
Takeoff	1300	97.2	64	—	—	—	—
Climb	1300	97.2	64	—	73	—	—
Cruise	1300	97.2	63	—	—	—	—
Power Approach	1300	97.2	63	—	—	—	—
Landing	1300	97.2	62	—	71	—	—
Takeoff	1220	103.6	61	68	70	86	86
Climb	1220	103.6	61	72	68	87	88
Cruise	1220	103.6	62	—	—	—	—
Power Approach	1220	103.6	62	—	—	—	—
Landing	1220	103.6	62	65	70	83	86
Takeoff	1310	103.9	65	70	69	88	85
Climb	1310	103.9	63	69	69	90	85
Cruise	1310	103.9	65	—	—	—	—
Power Approach	1310	103.9	64	—	—	—	—
Landing	1310	103.9	64	70	68	85	85

NOTE:

[1]Not tested

FIGURE 1
STALL SUMMARY
LONG-EZ USA S/N 82-1240 (N1253)

NOTE: 1. FORWARD C. G.
2. LANDING CONFIGURATION
3. CURVES DERIVED FROM TABLE 4



control forces were considerably higher than the 1g stalls. The longitudinal control had to be pulled against the aft stop to effect a stall. The pitch break was mild and the post-stall reactions were similar to the 1g stall characteristics. The mild stall reactions and controllability during the stall increases the pilot's confidence to maneuver. The accelerated stall characteristics failed to meet the requirements of paragraph 3.4.2.1.1 of MIL-F-8785C, in that there was no warning of approaching a stall. The accelerated stall characteristics of the LONG-EZ are satisfactory.

Landing Performance

14. Landing evaluations were conducted at the conditions listed in table 2. Landing approaches were from a normal downwind, base, and final approach pattern using 90 KIAS on downwind and slowing to a predetermined approach speed just after the turn to final and prior to intercepting the final descent path. The approaches were made at constant airspeed with power off except for occasional small power applications to adjust the touchdown point. Approaches made at 75 KIAS resulted in excessive float prior to touchdown (several hundred feet). Approaches made at 65 KIAS were accompanied by very little float and the glide path to touchdown could be adequately controlled with power. The ability to precisely control pitch and roll attitude made for a safe, comfortable approach at 65 KIAS in a low wind condition. After touchdown on the main wheels, the nose wheel was lowered to the ground immediately. Braking was excellent; the aircraft could be smoothly and rapidly stopped in a straight line. The landing performance capabilities at 65 KIAS compared favorably with the data presented in the owner's manual.

HANDLING QUALITIES

General

15. A limited handling qualities and pilot workload evaluation of the LONG-EZ was conducted to determine stability and control characteristics at the test conditions listed in table 3. Emphasis was placed on operation at the maximum gross weight and at the expected most critical condition of aft cg loading. All coordinated flight maneuvers were flown in trimmed (ball-centered) flight, where possible. One deficiency and fifteen shortcomings were identified. The potential loss of directional control due to single point brake failure during take-off/landing and ground handling was identified as a deficiency and is a safety-of-flight hazard. The major shortcomings affecting mission

versatility and pilot effectiveness were: decrease in engine power during low g maneuvers; limited directional control; excessive throttle freeplay; limited longitudinal trimmability; and inaccessability of the lateral trim system.

Control System Characteristics

16. Control system mechanical characteristics were measured on the ground with the engine stopped and qualitatively compared in flight at the conditions shown in tables 2 and 3. Control positions were measured using onboard instrumentation and were taken from the center of the forward cockpit side-arm control stick with longitudinal and lateral trim set to zero. Rudder pedal measurements were taken from the forward edge of each pedal. The cockpit controls versus control surface positions obtained during ground calibration and rigging check are presented in figure 14, appendix E. Table 5 is a summary of control system mechanical characteristics.

17. In flight, the longitudinal and lateral mechanical characteristics exhibited low breakout (plus friction) forces, adequate control force gradients, and positive control centering. There was no detectable lag in aircraft response to either small or large control inputs to any control axis. Control harmony was good and there was no tendency for the pilot to induce undesirable motion within the trimmable airspeed range.

Table 5. Control System Mechanical Characteristics

Test Parameters	Control Axis		
	Longitudinal	Lateral	Directional
Full Control Travel (in.)	3.0	5.0	2.0 left, 2.5 right
Control System Freeplay (in.)	0.2 FWD 0.2 AFT	0.2 right 0.2 left	None
Mechanical Coupling	None	None	None
Control Centering	Positive	Positive	Absolute
Control Oscillations	Convergent	Convergent	None
Trim Control System Breakout Force (plus friction) (lb)	5.4 fwd, 5.4 aft	2.4 left, 4.2 right	None
Trim Control System Freeplay (in.)	0.1 fwd, 0.1 aft	0.2 left 0.4 right	None
Control Forces Trimmable to Zero	No	Yes	No

Controls Positions in Trimmed Forward Flight

18. Control positions in forward flight were evaluated from 85 to 147 knots calibrated airspeed (KCAS) in conjunction with level flight performance at the conditions shown in table 3. The variation of control position and pitch attitude with airspeed is shown in figures 15 through 17, appendix E. The longitudinal control position variation with airspeed in level flight was conventional, in that increasing forward stick position was required with increasing airspeed. The lateral and directional control positions did not change with airspeed. Pitch attitude varied from 5 degrees nose up at 85 KCAS to level at 147 KCAS. Control margins at all airspeeds exceeded 10 percent. These characteristics decreased pilot workload in changing airspeeds and contributed to the pilot's ability to accurately attain a

desired airspeed within 3 knots (HQRS 3). The control positions in trimmed forward flight are satisfactory.

Trimmability

19. The capability to trim the aircraft to a given airspeed and zero control force was evaluated concurrently with other testing. A detailed description of the LONG-EZ trim systems is presented in appendix B.

20. The airspeed band at which longitudinal control forces could be trimmed to zero was cg dependent and limited to a maximum of 85 to 147 KCAS at full forward cg position (FS 97.0) and 80 to 141 KCAS at the aft cg position (FS 103.9). Within the longitudinal trim airspeed band precise longitudinal trim was difficult to achieve due to the high breakout plus friction forces (5.4 lb fore and aft) and trim system friction band. Because the trim system would overshoot, extensive pilot compensation was required to establish a precise airspeed ($\pm$1 knot) while reducing longitudinal control forces to zero (HQRS 6). Longitudinal control forces could not be trimmed to zero in any configuration while maneuvering above 147 KCAS and produced undesirable abrupt aircraft pitch response and tendencies toward pilot-induced oscillations (para 29). The longitudinal trimmability characteristics failed to meet the owner's manual criteria (ref 3, app A) and the requirements of paragraph 3.6.1 of MIL-F8785C, in that longitudinal control forces could not be reduced to zero throughout the operational flight envelope. The inadequate longitudinal trimmability is a shortcoming.

21. In order for the pilot to use the lateral trimming device he must remove his right hand from the side-arm control stick, lift or roll his right leg to the left and adjust the trim lever located in the right console. This technique is unsatisfactory in that the pilot is required to either transfer his controls (trimming with the right hand) and cross-control with the left hand, or reach across his body and awkwardly trim with the left hand only. Attaining precise lateral trim is further complicated by interference of the trim lever and the pilot's leg which results in numerous trim changes during flight, especially after takeoffs, during landings, and in maneuvering flight. At these conditions, the pilot elected to fly with approximately 3 to 5 pounds of lateral trim force required rather than continuously adjust trim (HQRS 6), thereby degrading mission effectiveness by inducing pilot fatigue. The lateral trimmability characteristics met the requirements of MIL-F-8785C. Decrease in pilot effectiveness due to the inaccessibility of the lateral trim system is a shortcoming.

22. Directional trim characteristics were satisfactory throughout the flight envelope although there was no cockpit-adjustable rudder trim. Due to the lateral-directional stability characteristics (paras 26 and 34), ball-centered flight was readily maintained in any configuration or condition tested with very light rudder forces.

Static Longitudinal Stability

23. The static longitudinal stability characteristics of the LONG-EZ airplane were evaluated at the conditions shown in table 4. The aircraft was trimmed in level flight at the desired trim airspeed, then stabilized in 5-KIAS increments up to 20 KIAS faster or slower than the trim airspeed while maintaining constant throttle and trim settings. Longitudinal control positions were measured and control forces qualitatively evaluated with the test results presented in figures 18 through 22, appendix E.

24. The apparent stick-free static longitudinal stability, as indicated by the variation of control force with airspeed about a trim airspeed, was positive for all configurations tested. With an aft cg, stick-free stability was less on the low-speed side of trim than on the high-speed side. With the longitudinal control trimmed at 80 to 82 KIAS, at airspeeds approaching a stall in the landing configuration the control force was approximately 2 to 3 pounds and was not objectionable.

25. The stick-fixed static longitudinal stability, as indicated by the variation of longitudinal control position with airspeed, was positive at climb and approach airspeeds to weakly positive at cruise airspeeds and above. The weak stick-fixed stability was not objectionable due to positive stick-free stability. The static longitudinal stability characteristics met the requirements of MIL-F-8785C. Within the scope of the tests, the static longitudinal stability of the LONG-EZ is satisfactory.

Static Lateral-Directional Stability

26. Static lateral-directional stability tests were performed at the conditions listed in table 3. The tests were conducted by trimming the aircraft (ball-centered), and then using the controls to generate steady heading sideslips at constant airspeed and throttle. Test data is presented in figures 23 through 26, appendix E. The sideslip indicator was a canopy-mounted yaw string marked in degrees from the longitudinal axis. Apparent dihedral (variation of lateral control position with sideslip)

and apparent directional stability (variation of directional control position with sideslip) were both positive. Directional stability was very strong as indicated by a rapid return to coordinated trim flight when the aircraft was released from sideslip. Pedal and lateral control forces were light but provided adequate cues to out-of-trim conditions. There was no control force lightening observed. Sideforce cues (variation of bank angle with sideslip) provided an additional indication of out-of-trim conditions. With extension of the landing brake, the directional stability was reduced. The maximum sideslip angles in the landing configuration were 14 degrees (indicated) left and 15 degrees right with full pedal displacement. This limited sideslip reduces the crosswind landing capabilities, and could reduce the ability to sideslip to shorten glide distance during normal or forced landings. These results are comparable to the 15 knot crosswind landing component limitation imposed by the owner's manual. The yaw and roll control power in the power approach and landing configurations met the requirements of MIL-F-8785C. The limited directional control is a shortcoming.

Maneuvering Stability

27. Maneuvering stability characteristics were evaluated at the conditions presented in table 4. The variation of longitudinal control position and control force with normal acceleration was determined by trimming the aircraft in coordinated (ball centered) level flight at 122 and 127 KCAS and full forward trim during diving flight at 170 KCAS, and then stabilizing at incremental bank angles in steady turns, both left and right. Airspeed and power were held constant and the aircraft was allowed to descend during the maneuver. Data were obtained at each stabilized bank angle. Symmetrical pull-up and pushover maneuvers were used to obtain load factors in excess of +2.0 and load factors below +1.0, respectively. These maneuvers were performed by diving and climbing the aircraft at constant power and establishing either increasing or decreasing increments of normal acceleration as the aircraft passed through the level flight attitude at the desired trim airspeed and altitude. Maneuvering stability data are presented in figures 27 through 31, appendix E.

28. The stick-fixed maneuvering stability, as indicated by the variation of longitudinal control position with normal acceleration, was slightly positive (increased aft longitudinal control position with increased load factor) and essentially linear for all conditions tested. The longitudinal control position gradient varied from approximately 0.3 inches per g at 127 KCAS to 0.2 inches per g at 170 KCAS for aft cg configurations to

0.5 inches per g at 127 KCAS for mid-forward cg configurations (FS 98.4). The decrease in stick-fixed maneuvering stability between 127 KCAS and 170 KCAS was not objectionable since bank angles up to 60 degrees (2.0g) at 127 KCAS and 30 degrees at 170 KCAS were easily maintained (HQRS 3). The stick-fixed maneuvering stability is satisfactory.

29. The variation of longitudinal control force with normal acceleration (apparent stick-free stability) was slightly positive and linear. Qualitatively, the longitudinal control force gradient was 5 to 10 pounds per g for all airspeeds tested with a slight decrease (approximately 3 to 5 pounds per g) with normal acceleration at all selected bank angles at 170 KCAS. The inability to trim the longitudinal control force at zero above 141 KCAS was objectionable (para 20) and produced undesirable abrupt aircraft pitch response with tendencies toward pilot-induced oscillations at bank angles above 30 degrees. The maneuvering stability met the requirements of paragraph 3.2.2 of MIL-F-8785C, except paragraph 3.2.2.3, in that there was a tendency for longitudinal pilot-induced oscillations while maintaining steady turns in excess of 30 degrees of bank at 170 KCAS. The tendency for longitudinal pilot-induced oscillations while maintaining steady turns in excess of 30 degrees of bank at 170 KCAS due to lack of longitudinal control force trimmability is a shortcoming.

30. During symmetrical push-overs to -0.5g at 127 and 170 KCAS a transient increase in fuel flow was observed associated with engine roughness, decrease in propeller speed, and increased airframe vibrations (VRS 7). Immediate increase in load factor resulted in a return to nominal engine operation. The decrease in engine power during low g maneuvers restricts maneuvering versatility and is a shortcoming. The following CAUTION should be included in the operating instructions.

CAUTION

Avoid sustained low g maneuvers due to engine roughness and decrease in power.

Dynamic Longitudinal Stability

31. The dynamic longitudinal stability characteristics were evaluated at the conditions shown in table 3. The long-term (phugoid) response characteristics were evaluated by varying the airspeed 10 and 20 KIAS above and below the trim airspeed, followed by returning the longitudinal control to the trim position (stick-fixed) or releasing the control and allowing it to seek the trim position (stick-free). Short-term dynamic characteris-

tics, simulating gust response, were evaluated by longitudinal control pulses (1 in. from trim for a duration of 0.5 sec). Representative times histories are presented in figures 32 and 33, appendix E. Test results are summarized in table 6.

Table 6. Dynamic Longitudinal Characteristics

Dynamic[1] Characteristics	Trim Indicated Airspeed (kt)	Period (sec)	Natural Frequency (rad/sec)	UnDamped Natural Frequency (rad/sec)	Damping Ratio
Long-term	120	30	0.224	0.209	0.365
Short-term	120	3.2	2.968	1.963	0.750

NOTES:

[1]Propeller speed: 2600 RPM, Gross weight: 1220 lb, CG: FS 103.8 (aft), cruise configuration.

32. The long-term (phugoid) response of the LONG-EZ was oscillatory, moderately damped, and not easily excited in the cruise configuration at 120 KIAS. The period was approximately 30 seconds. At trim airspeeds, the phugoid caused airspeed variations of less than 3 knots, but did not degrade aircraft control (HQRS 3). The long-term dynamic characteristics of the LONG-EZ met the requirements of MIL-F-8785C and are satisfactory.

33. Longitudinal short-term characteristics were essentially deadbeat for all test conditions, including flight in light and moderate turbulence. The short-term characteristics met the requirements of MIL-F-8785C. For the conditions investigated, the short-term longitudinal dynamic characteristics are satisfactory.

Dynamic Lateral-Directional Stability

Dutch Roll Characteristics:

34. The dynamic lateral-directional stability characteristics (lateral-directional damping and dutch roll characteristics) were

evaluated at the conditions shown in table 3. These tests were conducted by exciting the aircraft from a coordinated level flight trim condition with aileron pulses and doublets, rudder doublets, and release from steady-heading sideslips. Time histories of representative dynamic lateral-directional responses are presented in figures 34 through 36, appendix E. The lateral-directional oscillations were heavily damped and not easily excited. The dutch roll period was approximately two seconds with a damping ratio of approximately 0.7 and roll-to-yaw ratios of approximately 1:1.5. In light to moderate turbulence without pilot inputs the dutch roll tended to damp out in one or two cycles (HQRS 2). Within the scope of the test, the dutch roll characteristics of the LONG-EZ are satisfactory.

Spiral Stability:

35. The spiral stability characteristics of the LONG-EZ aircraft were evaluated at the conditions shown in table 3. These tests were conducted by establishing 10 and 20-degree bank angles (both left and right) from trim conditions, using aileron or rudder only, and then after stabilizing at the prescribed bank angle, the control was slowly returned to trim. Spiral stability, as indicated by change in bank angle with elapsed time was convergent for both left and right turns. Any small disturbance of the lateral or directional control system or gust would result in a tendency for the aircraft to return to trim without pilot compensation. Within the scope of the test, the spiral stability of the LONG-EZ is satisfactory.

Gust Response:

36. In light to moderate turbulence, extension of the landing air brake resulted in a roll oscillation with a tendency towards pilot-coupling. As a result of the pilot-coupled roll oscillation tendency, overcontrolling in roll during the landing task increased pilot workload while performing other critical functions such as power management and airspeed control (HQRS 5). The lateral trim change due to configuration change failed to meet the requirements of paragraph 3.6.3 of MIL-F-8785C, in that there were objectionable oscillations caused by the extension of the landing air brake. The roll oscillations in light to moderate turbulence with a tendency towards pilot-coupling when the landing air brake is extended is a shortcoming.

Roll Control Effectiveness

37. Roll control effectiveness was evaluated at the conditions shown in table 3. These tests were initiated from trimmed

unaccelerated flight conditions by applying 1/4 to full-lateral control inputs (in 0.2 sec) in approximately 1/4-inch increments without changing longitudinal or directional pedal control position. Representative time histories of airplane response with 1/2 and full deflection lateral control inputs are presented in figures 37 through 40, appendix E, and summarized for all deflections in table 7.

Table 7. Roll Control Effectiveness[1]

Control Deflection (in.)	Roll Mode Time Constant (T_R-sec)	Steady State Roll Rate (deg/sec)
Left		
0.4	0.18	9
1.1	0.16	24
1.3	0.16	23
2.6	0.16	42
Right		
0.4	0.18	7
1.1	0.16	20
1.4	0.14	25
2.2	0.16	38

NOTE:

[1]Trim airspeed 120 KIAS

Time required to roll 60 degrees left and right for full control deflections was 1.4 sec and 1.5 sec, respectively. Control forces were qualitatively determined to be light (less than 5 lb maximum) and proportional to control displacement with roll rates essentially constant during 60 degrees roll attitude changes. Roll-to-pitch and roll-to-yaw cross coupling was not noticeable and there were no adverse handling qualities. The roll control effectiveness met the Class I, Category B (light-reconnaissance airplane) requirements of MIL-F-8785C. Within the scope of the test, the roll performance characteristics of the LONG-EZ are satisfactory.

Trim Change Characteristics

38. Trim change characteristics due to variations in nose gear and landing air brake position were qualitatively evaluated in conjunction with other testing. The aircraft was trimmed in steady-heading, ball-centered flight at the desired condition and then a configuration change was made while holding one or more initial trim parameters constant.

Longitudinal Pitch Trim Changes:

39. Pitch trim changes, as a result of gear activation to the up position while in the takeoff configuration resulted in a slight nose up pitch response of 2 to 5 degrees which required less than 2 pounds of stick force (push) to maintain the desired climb attitude. Extension of either the nose gear or landing air brake was accompanied by an equally opposite pitch response requiring less than 2 pounds of pull force. A similar pitch down response (without any aircraft configuration change) was noted when flying in light rain. In all instances the magnitude of the pitch response was not objectionable and did not increase pilot workload. The pitch trim change characteristics met the requirements of MIL-F-8785C. The pitch trim change characteristics are satisfactory.

Ground Handling Characteristics

40. The ground handling characteristics of the LONG-EZ aircraft, which includes engine starting/shutdown, system checks, and taxiing were assessed throughout the evaluation. The hand-propping starting and shutdown procedure for the LONG-EZ as prescribed by the contractor (ref 3, app A) is simple and straight forward. The test aircraft, however, was not equipped with a carburator accelerator pump for automatic priming as recommended by the contractor and, consequently, starting was difficult. Because the fuel primer was located on the aft engine bulkhead, inboard of the propeller and at the highest point in the fuel system, cockpit priming was not possible and the engine starting sequence required numerious priming iterations (6 to 12 times) and hand-propping attempts (1 to 100) to start the engine, regardless of whether a cold or hot engine condition existed. The uncertainty of engine starting severely restricts mission reliability and response time. Inaccessability of the fuel primer during engine cranking is a shortcoming.

41. Ground taxiing was accomplished on paved level surfaces. During normal taxi operations, a fast-walk taxi speed was achieved with RPM set between 800 to 1000. Directional control was

maintained by differential braking of the main gear. The brakes were effective and did not fade after heating up in excess of 300°C from hard braking. Under zero wind conditions, once the desired caster angle of the nose gear was achieved, the direction of turn and turn radius could be maintained without further braking (HQRS 3). With 15 knot crosswinds (maximum tested) continuous light to heavy braking was required to maintain directional control (HQRS 6). At taxi speeds greater than 45 KIAS, the combination of rudder and differential light to moderate braking was adequate to maintain directional control. During one taxi operation, the left brake became inoperative due to the piston binding on the brake actuating cylinder assembly causing loss of directional control and an emergency engine shut-down was required to prevent the aircraft from exiting the taxiway (HQRS 9). The loss of directional control during ground handling, take-off or landing due to a single point brake failure constitutes a safety-of-flight hazard. The ground taxi characteristics met the requirements of MIL-F-8785C. The loss of directional control during ground handling, takeoff or landing due to a single point brake failure is a deficiency. The following WARNING should be included in the aircraft operating instructions.

WARNING

> Single point brake failure will probably result in loss of aircraft directional control during take-off/landings and ground handling at airspeeds less than 45 KIAS.

42. Minimum turning radius was determined by applying maximum differential braking and engine thrust as required to achieve maximum turning performance. Results of the test are presented in figure 41, appendix E. The minimum turning radius of 20.1 feet (wing radius) is satisfactory.

Power Management

43. Engine handling characteristics of the LONG-EZ were qualitatively evaluated throughout the evaluation. Power management required high pilot workload due to variable throttle system freeplay (0.5 to 0.75 in.) and forces required for throttle displacement throughout the range of travel. The resultant effect caused overshoot or jerky throttle manipulations which degraded precise glide path and touchdown point control during landing approaches. The excessive throttle freeplay is a shortcoming.

44. During high-speed flight at high power settings, maximum power limits were sensitive to airspeed changes. In this regime, propeller speed had to be closely monitored to avoid exceeding maximum propeller speed limits. This task was further complicated by the size, shape and close proximity of the power management controls on the engine quadrant. On several occasions, while maneuvering, the pilot either initially grasped the mixture lever instead of the throttle or his sleeve caught on the mixture lever while retarding the throttle lever. This condition was alleviated by shortening the mixture control lever to half its original length. The original size, shape and close proximity of the power management controls on the engine quadrant is a shortcoming.

Mission Maneuvering Characteristics

45. The mission capability of the LONG-EZ was qualitatively evaluated in conjunction with other testing by conducting accelerations, decelerations, maneuvering flight, target designation, target tracking and rapid target shift maneuvers. The performance of these maneuvers below 147 KCAS exhibited an excellent potential for the light observation/reconnaisance mission for the following reasons: benign stall characteristics; positive longitudinal static stability; minimal lateral and directional trim changes with airspeed; well damped dynamic longitudinal and lateral-directional stability characteristics; and moderate roll response. The lack of longitudinal trimmability and close attention required to prevent exceeding engine limits above 147 KCAS limits mission effectiveness by increasing pilot workload. Additionally, chase pilots indicated that the aircraft was difficult to see in flight and difficult to rapidly ascertain its attitude and closure rate. This characteristic increases its tactical capability of mission accomplishment, but presents a potential hazard by increasing the possibility of a mid-air collision in a non-combat situation. The mission maneuver characteristics of the LONG-EZ are satisfactory. The following WARNING should be placed in the operator's manual.

WARNING

> It is difficult to see and determine the attitude and the closure rate of the LONG-EZ aircraft.

Simulated Engine Failure Characteristics

46. The response of the aircraft to a sudden engine failure was evaluated in conjunction with drag polar determination during

glide tests. Sudden engine failures were conducted at maximum rated power climbs, low power descents, and in forward level flight at airspeeds to 127 KCAS. Flight controls were held fixed for 2 seconds following the power loss or until an aircraft attitude or angular rate dictated recovery initiation. Aircraft reaction to engine failures was benign with no changes in aircraft handling characteristics following simulated engine failure or shutdown. In order to stop the propeller from windmilling, it was necessary to decelerate to less than 60 KCAS. Engine restarts were performed in accordance with the contractor's recommended procedure (ref 3, app A) and were accomplished with less than 900 feet altitude loss with the propeller windmilling above 115 KCAS. Best glide speed at maximum gross weight and forward cg location was approximately 80 KCAS with propeller stopped. The simulated engine failure characteristics are satisfactory.

STRUCTURAL DYNAMICS

Vibration Characteristics

47. Vibration characteristics of the LONG-EZ were qualitatively evaluated throughout the test program and quantitatively evaluated at the conditions listed in table 3. Vibration characteristics were measured at the left wing spar and are presented in figures 42 through 45, appendix E. An objectionable engine/propeller vibration characteristic was experienced between 90 to 100 KCAS at power required for level flight or greater (engine RPM 1900-2800). The vibration was perceived as a medium frequency resonant response of approximtely 28 Hz (VRS 5). Additionally, within this airspeed range radio communications were degraded by the overall vibration characteristics of the airplane. The vibration characteristics met the requirements of MIL-F-8785C. The engine/propeller vibration characteristic between 90 to 100 KCAS at power required for level flight or greater is a shortcoming.

48. During roll control effectiveness evaluation (table 3) a slowly divergent aileron aerodynamic buffet was observed at maximum left control deflection. A sample time history is presented in figure 46, appendix E. Analysis of this safety-of-flight hazard indicated: excessive aileron control system freeplay (0.25 in. of aileron trailing edge travel, up and down); left aileron leading edge interference with the wing aileron slot at full control travel; and unsymmetrical contour of the left aileron leading edge. The problem was resolved by: reducing the aileron control system freeplay to 0.1 inch of trailing edge travel by replacing all AN hardware with ANS hardware and stiffening the

aileron bellcrank with a 1.25 inch aluminum spacer; eliminating all aileron interference; and rounding the left aileron leading edge to as nearly semicircular as possible.

Structural Load Verification

49. Wing and canard static load tests were conducted to 80 percent of maximum design load by AVRADCOM engineers with USAAEFA assistance. Test results are presented in appendix F. The establishment of a +4.0 to -1.0 load factor flight envelope is considered satisfactory for the intended concept feasibility evaluation.

Dynamic Aeroelastics

50. Frequency and modal damping of pertinent resonant modes of all control surfaces and airfoil surfaces were quantitatively determined by AVRADCOM engineers with USAAEFA and NASA assistance at the NASA-Dryden Flight Research Facility, Structural Laboratory, and qualitatively determined in flight at the conditions listed in tables 2 and 3. Results of the AVRADCOM tests are presented in appendix G, with a representative time history of flight test data shown in figure 47, appendix E. The structural dynamic characteristics of the LONG-EZ are satisfactory.

HUMAN FACTORS

Cockpit Evaluation

51. A ground cockpit evaluation of the LONG-EZ was conducted during daylight conditions from the pilot station with the aircraft in a static condition. The evaluator was attired in summer nomex flight suit, cold weather flyers jacket (type CNU-45/P), cold weather flying boots, nomex flight gloves, HGU-26/P flight helmet, and a Scott 250 parachute. Crew ingress/egress, cockpit layout, cockpit controls, instruments and placards, field-of-view, and crew comfort were evaluated individually and sequentially as prescribed in both normal and emergency procedure checklists. Evaluation of controls included an assessment of location, accessibility, and function design and operation. Instruments and placards were evaluated for location and clarity of information presented. Throughout all flights, a qualitative assessment of cockpit controls and procedures was performed. All measurements were made with the pilot inclined 20 to 40 degrees to the horizontal. The evaluation pilots' anthropometric measurements are summarized in table 1, appendix D.

Ingress/Egress:

52. Normal ingress/egress from the cockpit was accomplished with the aircraft parked nose-down. The pilot, after stepping over the longerons into the seat pan must grasp each longeron and lower his legs through the instrument panel cut-outs to attain a seating position. On each occasion while lowering his legs into position the pilot's flight suit hem became entangled with either the radio panel control knobs on the left or the cylinder head temperature/exhaust gas temperature (CHT/EGT) control knob on the right, or both with a potential of damaging equipment due to inadequate leg clearance through the instrument panel. Once seated the pilot's legs would rub the lower instrument panel which inhibited egress. The inadequate leg clearance with the instrument panel is a shortcoming.

53. An optional step was provided for normal ingress/egress with the aircraft parked on all three landing gear. Both entry and exit by this manner was undesireable due to awkward and unbalanced body position necessary to step over the left leading edge of the fuel strake into the cockpit.

54. Emergency egress was evaluated on the ground under simulated emergency conditions. Ground emergency egress was hindered by inadequate leg clearance with the instrument panel (para 52) and operation of the canopy unlatch warning system and the safety catch. Approximately 9 to 11 seconds were required for emergency egress from the aircraft due to the safety catch inhibiting egress by reengaging after initial release. In-flight emergency egress would be further restricted due to the lack of a quick-release canopy jettison capability. The lack of a quick release canopy jettison capability during emergency egress is a shortcoming.

Field-of-View:

55. The pilot station field-of-view was qualitatively evaluated with the pilot seating adjusted to approximately the 50th percentile design eye height (DEH) position of 31.5 inches. The viewing limits are presented in figures 48 through 50, appendix E. The effective horizontal field-of-view was restricted from 119 to 128 degrees right and 231 to 240 degrees left by the winglets, and from 140 degrees right to 210 degrees left by the cabin rollover structure. Forward and to the left and right front quadrants, the pilot's field-of-view was mildly distorted by the curved canopy juncture with the canopy frame assembly. Vertically the pilot was limited from 9 to 16 degrees below the horizontal by the canard and to 80 degrees above the horizontal due to helmet

interference with the cabin rollover structure. The field-of-view from the cockpit is satisfactory.

56. Fuel management procedures required the pilot to visually check the fuel quantity in each selectable wing tank. This was not possible from the front cockpit since the pilot could not see each wing tank fuel level window since it was obstructed by the cabin rollover structure. Fuel management was accomplished by use of a fuel totalizer located in the right wing strake baggage area. The lack of the fuel monitoring capability during solo operations is a shortcoming. The following NOTE should be placed in the operator's manual.

NOTE

> For solo operations, a fuel monitoring system is required.

RELIABILITY, AVAILABILITY AND MAINTAINABILITY

57. The reliability, availability and maintainability of the aircraft was evaluated throughout the test program. During actual flight testing, the high availability and minimal maintenance down time due to the simplicity of design and ease of repair of composite structures were noteworthy. Prior to flight testing the following safety of flight and construction deficiencies were noted and corrected.

a. Safety-of-Flight:

(1) Improper left wing incidence angle
(2) Improper canard angle of incidence
(3) Improper left and right aileron mass balance
(4) Insufficient elevator travel
(5) Insufficient right and left rudder travel
(6) Insufficient aileron travel
(7) Left fuel cell leak aft of bulkhead in the center section spar
(8) Improper right main gear toe-in angle
(9) Improper installation of both brake master cylinders
(10) Improper fabrication of canopy latch assembly
(11) Inadequate locking mechanism on engine primer
(12) Longitudinal and lateral control interference with fuselage structure
(13) Lateral trim control binding with brake lines
(14) Longitudinal control system binding with aircraft wiring and fuselage structure

(15) Improper main landing gear tire pressure

b. Maintenance:

(1) Improper landing airbrake tension
(2) Improper brake adjustment
(3) Excessive aileron control system freeplay
(4) Excessive elevator breakout plus friction
(5) Use of improper aircraft hardware and control system linkage and wing attachment bolts
(6) Improper carburator air induction system
(7) Improper and inadequate engine tachometer system
(8) Improper nose wheel caster friction
(9) Irregular canard surface contour
(10) Inoperative canopy warning microswitch
(11) Aircraft instrumentation/avionics electro-magnetic interference (EMI)
(12) Rudder drain holes not installed
(13) Improper fuel mixture adjustment
(14) Right brake actuating lanyard binding on bellcrank
(15) Improper engine-ignition timing
(16) Excessive freeplay in engine controls
(17) Battery cable not properly secured to battery
(18) Control grip rotates on control rod
(19) Top engine cowling cooling baffles not installed

58. Throughout the evaluation, the designer recommended maximum power static RPM check (2450 RPM minimum) could not be achieved. The maximum static power consistently obtained with either a 60 inch diameter 76 degree (flat bottom reference) or 60 inch 66 degree pitch propeller was 2350 RPM at 25.95 inches of mercury manifold pressure. The failure of the propeller/engine combination to produce the recommended static power RPM limited take-off and climb performance. The propeller/engine maximum static power check failed to meet the designer recommended minimum static power. The engine/propeller maximum static power RPM is adequate for the intended concept feasibility evaluation.

59. Throughout the evaluation, EMI was evaluated for effect on various aircraft electrical systems. The only component observed producing EMI was the very high frequency (VHF) radio transmitter. Keying the VHF radio momentarily rendered several telemetered data parameters unuseable, increased the cockpit propeller RPM indication by 200 RPM, changed the cockpit cylinder head indicator by several hundred degrees, and made a slight change in the magnetic heading indicator. Numerous times during the evaluation the tachometer propeller RPM indicator exceeded the 2800 RPM limit while transmitting. At high airspeeds the propeller RPM

is sometimes close to the maximum allowed requiring the pilot to closely monitor the tachometer. The false increase in propeller RPM indications caused by the VHF transmitter is a nuisance requiring additional alertness on the part of the pilot and is a shortcoming.

MISCELLANEOUS

Weight and Balance Determination

60. Prior to flight testing, a weight and balance determination was conducted on the aircraft in the uninstrumented and instrumented configurations. A post-evaluation weighing was conducted to verify gross weight and cg location after test instrumentation was removed. The results of the weight and balance due to fuel loading are presented in figure 51, appendix E. The aircraft basic weight and cg were 820 lb at FS 112.7 uninstrumented, and 917 lb at FS 110.8 instrumented.

Pitot-Static System Calibration

61. The pitot-static position error of the standard ship's system was determined at conditions presented in table 2 using the calibrated pace method. The test results are presented in figure 52, appendix E. The maximum position error was +10 knots at 70 KIAS and gradually decreased to 1/2 knot error within the airspeed range of 140 to 180 KIAS. During steady heading sideslip in either direction, the calibrated airspeed position error varied significantly (+8.5 knots at 9.5 degrees left sideslip and -0.5 knots at 4.5 degrees right sideslip) from calibrated position errors and trimmed level flight. The position error characteristics of the ship's airspeed system are satisfactory. The following NOTE should be included in the operator's instruction manual.

NOTE

> Airspeed position error will vary significantly with left sideslip.

Engine Cooling Characteristics

62. Engine cooling characteristics were evaluated throughout the tests and at the conditions listed in table 2 during maximum continuous power climbs from 82 to 91 KCAS. Engine cooling baffles as prescribed in the LONG-EZ manufacturing manual were not installed in the test aircraft. During the tests the outside air temperature (OAT) varied from 10 to 72 degrees fahrenheit (°F).

Cylinder head temperatures (CHT) varied from a maximum of 421°F at the number four cylinder to 294°F at number one cylinder. Nominal level flight CHTs at 100 to 147 KCAS varied from 384°F at the number four cylinder to 278°F at the number one cylinder. During ground operations at 60 to 72°F OAT at an engine speed of 700 RPM, the number four cylinder exceeded the maximum continuous limit of 435°F while the maximum observed number one CHT was 394°F. While maintaining engine RPM at 1000, there was a decrease in all CHT indications to within permissible limits. The disparity in engine cooling characteristics between the CHT's increases pilot workload in monitoring engine performance limits. The following NOTE should be included in the operator's instruction manual.

NOTE

During prolonged ground operations, minimum engine RPM should be 1000 RPM to avoid exceeding maximum continuous CHT.

CONCLUSIONS

GENERAL

63. The following conclusions were reached upon completion of the PAE evaluation of the LONG-EZ aircraft:

a. The test aircraft (S/N 82-1240; N1253) exhibited excellent potential for the light observation/reconnaisance mission and is satisfactory for the intended concept feasibility evaluation (para 45).

b. The high availability and minimal maintenance down time due to ease of repair of composite structures during flight testing of the LONG-EZ were noteworthy (para 57).

c. Test results compared favorably with information presented in the owner's manual (para 6).

d. One deficiency and fifteen shortcomings were noted during these tests (para 6).

DEFICIENCY

64. The loss of directional control due to single point brake failure during take-off/landing and ground handling (para 41).

SHORTCOMINGS

65. The following shortcomings were identified and are listed in decreasing order of relative importance:

a. Lack of a quick release canopy jettison capability during emergency egress (para 54)

b. Absence of stall warning (para 12)

c. Decrease of engine power during low g maneuver restricts maneuvering versatility (para 30)

d. Excessive throttle freeplay (para 43)

e. Limited directional control (para 26)

f. Tendency for longitudinal pilot-induced oscillations while maintaining steady turns in excess of 30 degrees of bank at 170 KCAS (para 29).

g. Tendency for pilot-coupled roll oscillations in light to moderate turbulence when the landing air brake is extended (para 36)

h. Inadequate longitudinal trimmability for all cg configurations (para 20)

i. Inaccessability of the lateral trim system (para 21)

j. Inaccessibility of the fuel primer during engine cranking (para 40)

k. Size, shape and close proximity of the power management controls on the engine quadrant (para 44)

l. Engine/propeller vibration characteristics between 90 to 100 KCAS at power required for level flight or greater (para 47)

m. Inadequate leg clearance with the instrument panel (para 52)

n. Lack of fuel monitoring capability during solo operations (para 56)

o. False increase in propeller RPM indication caused by the VHF transmitter (para 59)

OWNER'S MANUAL COMPARISON

66. Within the scope of this test, the LONG-EZ aircraft compared favorably with the information presented in the owner's manual except for the following.

a. Longitudinal trimmability characteristics in that longitudinal control forces could not be reduced to zero throughout the operational flight envlope (para 20).

b. Minimum static power in that the propeller/engine maximum static power check failed to meet the minimum static power required (2450 RPM) (para 58).

SPECIFICATION COMPLIANCE

67. The LONG-EZ aircraft met all the requirements of the specification, MIL-F-8785C against which it was tested except for the following.

a. Paragrah 3.2.2.3 in that there was a tendency for longitudinal pilot-induced oscillations while maintaining steady turns in excess of 30 degrees of bank at 170 KCAS (para 29).

b. Paragraph 3.4.2.1.1 in that the LONG-EZ did not have an easily perceptible warning of approaching stall (para 12).

c. Paragraph 3.6.1 in that longitudinal control forces could not be reduced to zero throughout the operational flight envelope (para 20).

RECOMMENDATIONS

68. The deficiency identified during this evaluation should be corrected as a matter of highest priority if development continues (para 6).

69. The shortcomings should be corrected prior to production (para 6).

70. Incorporate the following WARNINGS in the operator's manual:

a. From paragraph 41 of this report:

WARNING

Single point brake failure will probably result in loss of aircraft directional control during take-off/landing and ground handling at airspeed less than 45 KIAS.

b. From paragraph 45 of this report:

WARNING

The LONG-EZ aircraft is difficult to see in flight and difficult to rapidly ascertain its attitude and closure rates.

71. Incorporate the following CAUTIONS in the operator's manual:

a. From paragraph 12 of this report:

CAUTION

Full stall landings should be avoided due to lack of stall warning.

b. From paragraph 30 of this report:

CAUTION

Avoid sustained low g maneuvers due to engine roughness and decrease in power.

72. Incorporate the following NOTES in the operator's manual:

a. From paragraph 56 of this report:

NOTE

For solo operations, a fuel monitoring system is required.

b. From paragraph 61 of this report:

NOTE

Airspeed position error will vary significantly with left sideslip.

c. From paragraph 62 of this report:

NOTE

During prolonged ground operations minimum engine RPM should be 1000 RPM to avoid exceeding maximum continuous CHT.

APPENDIX A. REFERENCE

1. Federal Air Regulation, Federal Aviation Administration, FAR Part 21, *Certification Procedures for Products and Parts,* 1 January 1981.

2. Letter, AVRADCOM, DRDAV-DI 30 December 1982, subject: Preliminary Airworthiness Evaluation of the Rutan Aircraft Factory (RAF), Inc. LONG-EZ Airplane. (Test Request)

3. Owner's Manual, Rutan Aircraft Factory, Inc, *LONG-EZ Aircraft,* Second edition, October 1981,

4. Letter, AVRADCOM, DRDAV-D, 6 April 1983, subject: Airworthiness Release for Rutan Aircraft Factory (RAF), Inc. LONG-EZ Aircraft S/N 1240.

5. Military Specification, MIL-F-8785C, *Flying Qualities of Piloted Airplanes,* 5 November 1980.

6. Letter, AVRADCOM, DRDAV-D, 12 February 1983, with revision 1, 24 February 1983, subject: Experimental Airworthiness Release for Rutan Aircraft Factory (RAF), Inc. LONG-EZ Aircraft S/N 1240.

7. Flight Test Manual, Naval Air Test Center, FTM No. 104, *Fixed Wing Performance,* July 1977.

8. Flight Test Manual, Naval Air Test Center, FTM No. 103, *Fixed Wing Stability and Control,* 1 January 1975, revised 1 August 1972.

9. Detailed Specification, No. 2499-G, *AVCO Lycoming Aircraft Engine Model 0-235-L2A, -L2C,* 5 February 1982.

10. Federal Air Regulation, Federal Aviation Administration, FAR Part 91, *General Operating and Flight Rules,* 1 January 1981.

11. Sighard F. Hoerner, *Fluid Dynamic Drag,* 1965.

12. Courtland D. Perkins and Robert E. Hage, *Airplane Performance Stability and Control,* John Wiley & Sons, Inc., 1967.

APPENDIX B. DESCRIPTION

GENERAL

1. The LONG-EZ airplane is a small, lightweight, home-built experimental class aircraft designed by Rutan Aircraft Factory (RAF), Inc. and privately constructed according to the LONG-EZ manufacturing plans. It is certified in the experimental category under FAR Part 21 (ref 1, app A) and operated in accordance with the provisions of FAR Part 91 (ref 10, app A). A three-view drawing of the aircraft with dimensions and general data is presented in figure 1 and photos 1 through 3. A complete description of the aircraft is contained in the owner's manual (ref 3, app A).

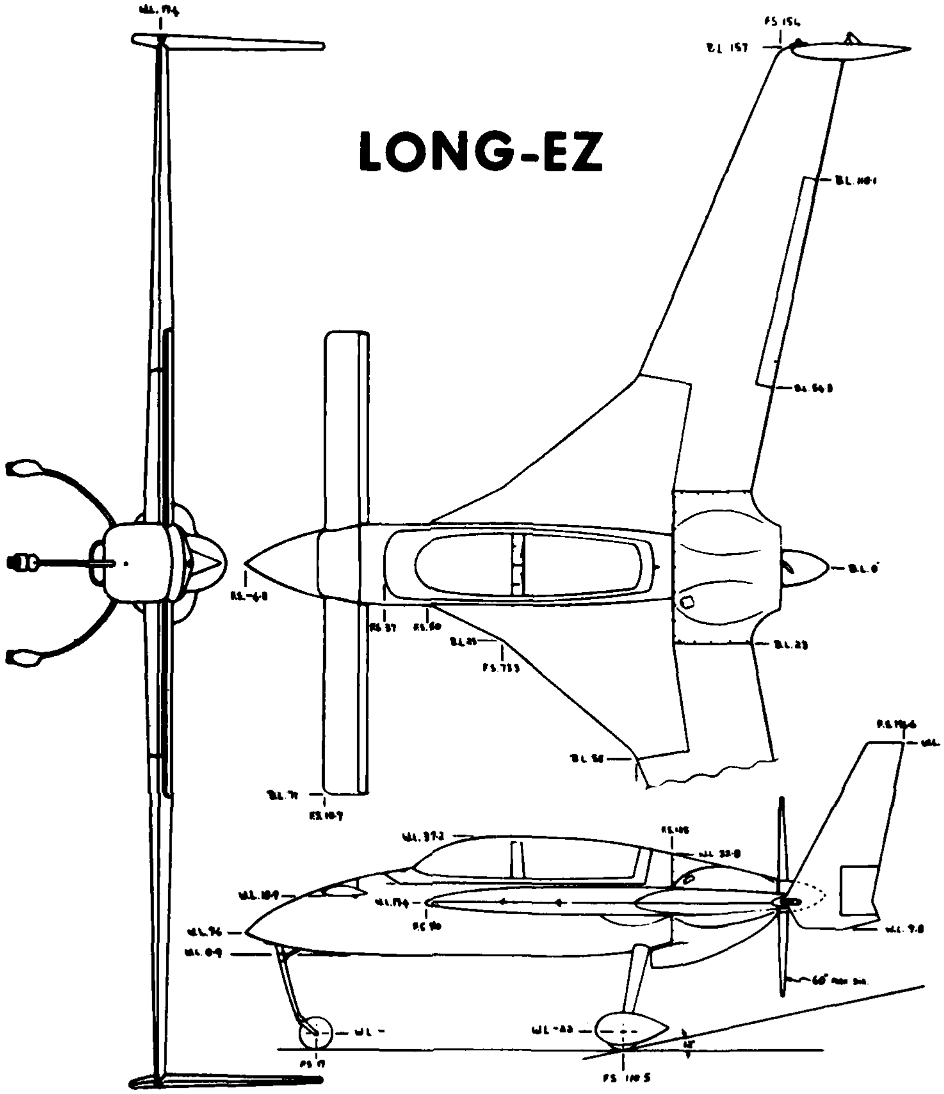
AIRFRAME

2. The airframe structure, primary airfoil surfaces and control surfaces of the LONG-EZ are designed around a composite sandwich material construction (fig. 2). The fuselage and fuel tanks, located in each forward wing root, are constructed of low density poly vinyl (PV) core foam. The mid-wing, high aspect ratio, modified Eppler 1230 swept airfoils, winglets, elevators and canard are formed by low density styrofoam with medium density PV-core used in the center section spar and canard inserts. Low density urethane foam is used in nonstructural areas around the nose section and canopy. Primary structural loads are carried by bi-directional and unidirectional fiberglass cloth bonded to a form core through an epoxy resin layup process.

LANDING GEAR

3. The LONG-EZ features a tricycle landing gear with fixed mains and a full castering, retractable nose wheel. The main landing gear is a one-piece, molded S-fiberglass/epoxy unit. To minimize drag penalty with fixed main gear, the gear strut is molded into an airfoil shape. The retractable nose gear strut is also molded S-glass, and is mechanically actuated by a crank lever in the front cockpit (fig. 3). The nose gear may be retracted in flight and also on the ground to provide nose-down parking and permit ease of ingress/egress from the aft cockpit. Nose gear position is displayed to the pilot through a plexiglass window, through which he views the nose wheel directly.

4. The main landing gear uses Cleveland 5-inch wheels and brakes. A low-profile 3.40 x 5 industrial rib 6 ply tire is used. The nose wheel is 4-inch diameter and uses a 2.80-2.50-4 tire and tube.



DIMENSIONS AND GENERAL DATA

WING SPAN	26.1 FT	ENGINE LYCOMING	0-235 L2C
WING AREA	94.8 SQ FT	RECOMMENDED FUEL	100LL OR 100/130
CABIN		MAX FUEL CAPACITY	52 GALLONS
LENGTH	100 IN	MAX GROSS WEIGHT	1325 LB
WIDTH	23 IN		
HEIGHT	37 IN		

Figure 1. Dimensions and General Data

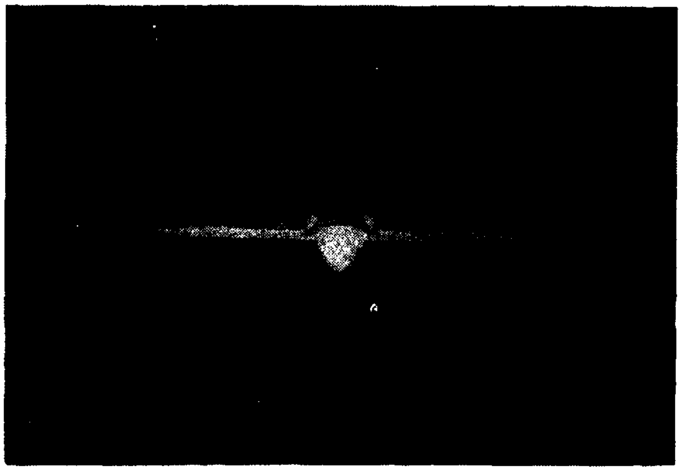


Photo 1. Front View

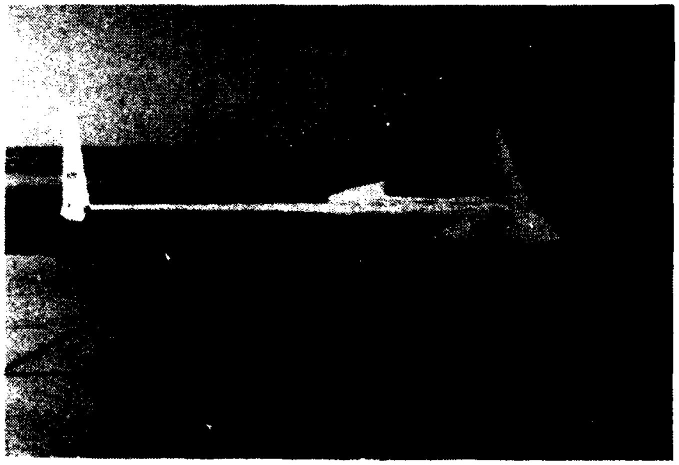


Photo 2. Right Quartering View

Photo 3. Top View

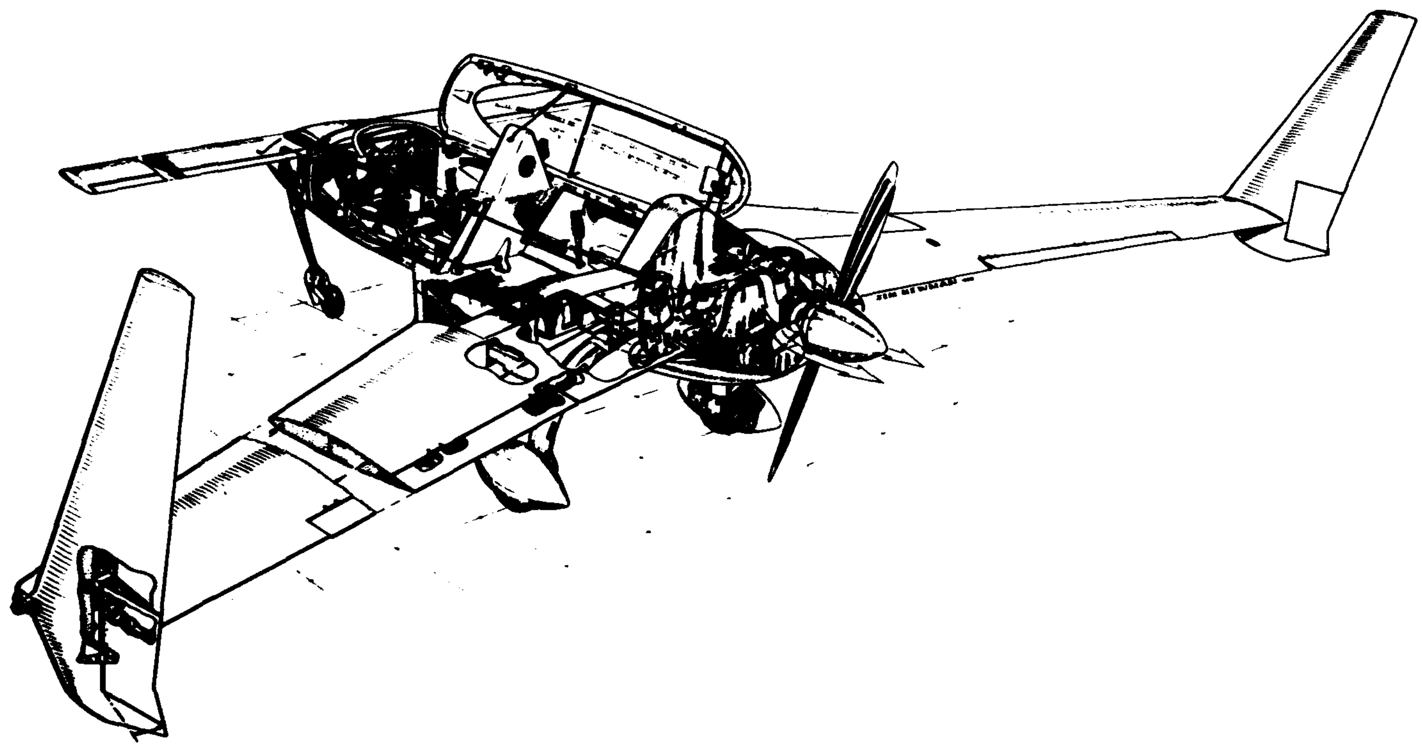
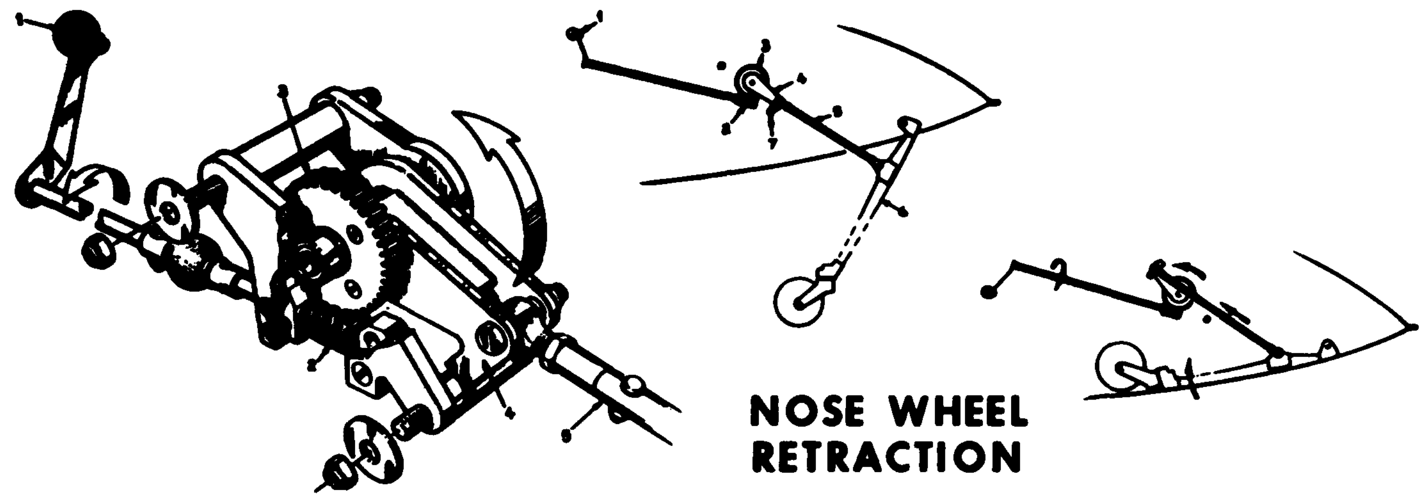


Figure 2. General Construction



Operation of Crank Handle (1) Drives worm gear (2) and gear (3) The yoke (4) being on a common shaft with the gear - lifts, rotating rearwards +180°, pulling rod (5) with it which lifts the nose wheel strut (6) to the retracted position.

The nosewheel is locked in the 'down' position by the over center position of the yoke and rod - rearwards thrust of the rod attempting to force the yoke downwards, where it bears solidly against the gross member (7).

Figure 3. Nose Gear System

5. The LONG-EZ is equipped with a buzzer gear-warning system which is actuated at low power settings with the gear up.

PROPULSION SYSTEM

Engine

6. Propulsion is provided by a rear dynafocal mounted, carbureted, four cylinder, Lycoming 0-235-L2C FAA type certified reciprocating engine. The engine has a maximum rated takeoff and continuous brake horsepower (BHP) rating of 118 BHP at 2800 engine RPM for standard day sea level conditions. Recommended minimum octane aviation grade fuel is 100/100 LL. Accessory provisions are provided for an alternator, starter and vacuum pump.

Propeller

7. Only lightweight fixed-pitch solid wood propellers are approved for installation on the LONG-EZ. The test aircraft (N1253) is configured with a Ted Hendrickson (Snohomish, Washington) designed and manufactured cruise propeller (diameter: 62 in. pitch: 66 degrees flat bottom reference). The wooden propeller incorporates an epoxy resin leading edge to minimize erosion. Manufacturers propeller efficiency factor data is not available.

FUEL SYSTEM

8. The fuel system consists of two 26 gallon individually selectable wing tanks, one in each forward wing root section. A three way selector (LEFT, RIGHT, OFF) is located on the thigh support center console just aft of the nose wheel position window. There is no provision for fuel transfer or for feed from both tanks simultaneously. Two fuel sump blisters located under each fuel tank at the fuselage junction are designed to supply fuel to the engine in all normal flight attitudes. Each tank is individually vented. Vent location is on the center upper fuselage just aft of the canopy. A mechanical engine-driven fuel pump transfers fuel from the selected tanks to the carburetor. An auxillary electric fuel pump provides backup for the engine-driven pump. The electric fuel pump provides fuel pressure redundancy during low altitude operation, such as takeoff and landing, and when the engine-driven pump fails. Fuel pressure is indicated on a gauge in the cockpit.

9. There are three fuel drains on the airplane, one in the leading edge of each fuel tank strake and one on the gascalator mounted on the fire wall. The gascalator is accessible through the air scoop under the cowling for draining during preflight. The tanks cannot be completely filled with nose down parking. To fill the tanks to the full 52 gallon capacity the nose wheel must be extended to level the aircraft. The nose can be lowered after full up fueling with the caps on without leaking, although heat expansion may force fuel out the vents.

BRAKE SYSTEM

10. Hydro-mechanical brakes are provided on the main wheels (fig. 4). They are intended to be used together for deceleration on the ground and individually for directional control at low speed on the ground. The brake actuating mechanism is the rudder pedal: after full rudder deflection is reached, the brakes are actuated. The brake master cylinder is the rudder stop. This system is designed to aid in keeping brake maintenance low by insuring that full aerodynamic control or braking is employed before wheel brakes are applied.

11. A parking brake is provided by the rubber bumper on the nose gear (nose down parking). For those aircraft not equipped with a starter and started without a ground crew member there is a brief period, after the engine is hand prop started, while the pilot enters the cockpit, that the aircraft could roll forward before he can get his feet on the brakes.

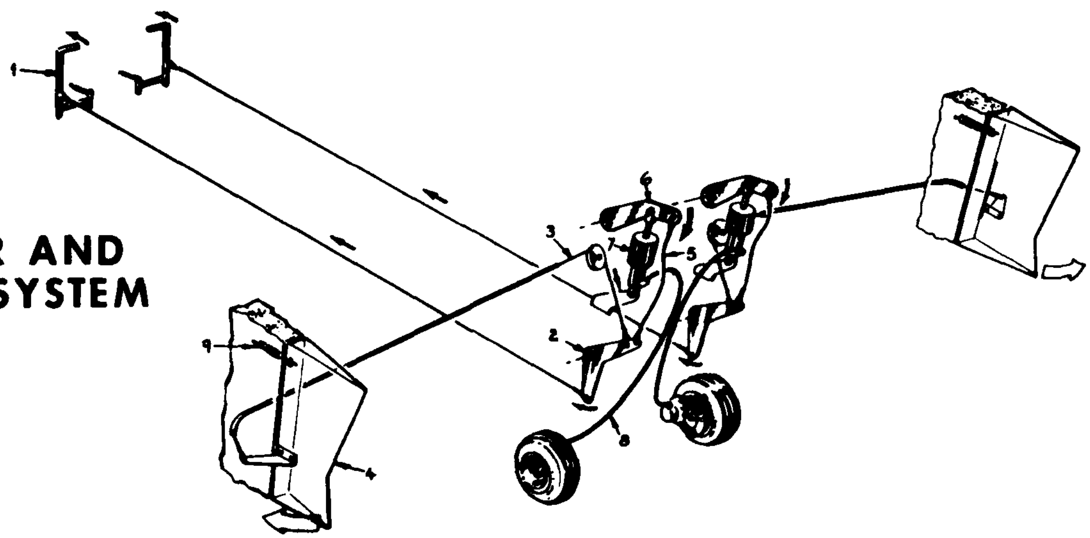
LANDING AIRBRAKE

12. A drag device is used to allow a steeper approach and to provide more deceleration in the flare (fig. 5). This belly-mounted landing airbrake is deployed by a lever on the left console. It is normally extended on downwind after gear extension and left down until after landing. Maximum speed with the airbrake down is 90 knots (105 mph). Above 95 knots (110 mph) air loads cause the brake to automatically close. During landing and taxiing the deployment of the speed brake provides some prop protection from rocks being kicked up by the nose wheel.

ELECTRICAL SYSTEM

13. Standard electrical power is provided by a negative ground, 12 volt direct current system (fig. 6).

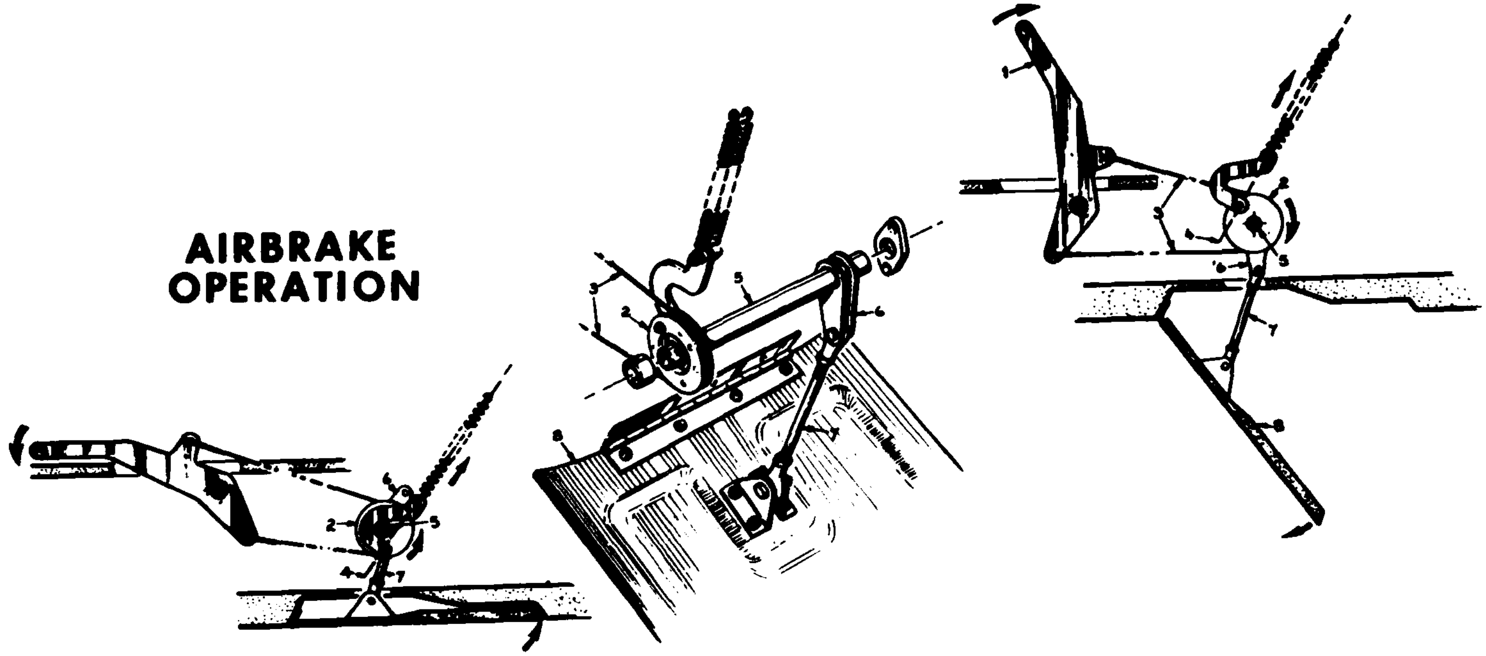
RUDDER AND BRAKE SYSTEM



The rudders deflect in an outwards direction only. Pressure on a rudder pedal (1) rotates bellcrank (2) which tensions the rudder cable (3), thus pulling rudder (4) around to an outwards deflection, further movement of the rudder pedal hence the bellcrank also - takes up slack in the brake cable (5) which pulls lever (6) downwards to actuate brake cylinder (7) rudders are returned to neutral by a combination of air load and spring load (9).

Figure 4. Rudder and Brake System

AIRBRAKE OPERATION



Pulling up and back on operating handle (1) rotates pulley (2) by means of cables (3). When the axis of the spring load (4) rotates to a point just forward of the torque tube (5), the spring load assists rotation of the pulley and crank (6) such that push rod (7) forces airbrake (8) downwards. Excessive air load on the brake reverses the action such that the force is transmitted back along the push rod (7) to cause crank and pulley to rotate counter clockwise, thus, when the axis of the spring load (4) moves to a point just past the torque tube (5), the spring will then automatically retract the airbrake.

Figure 5. Landing Airbrake

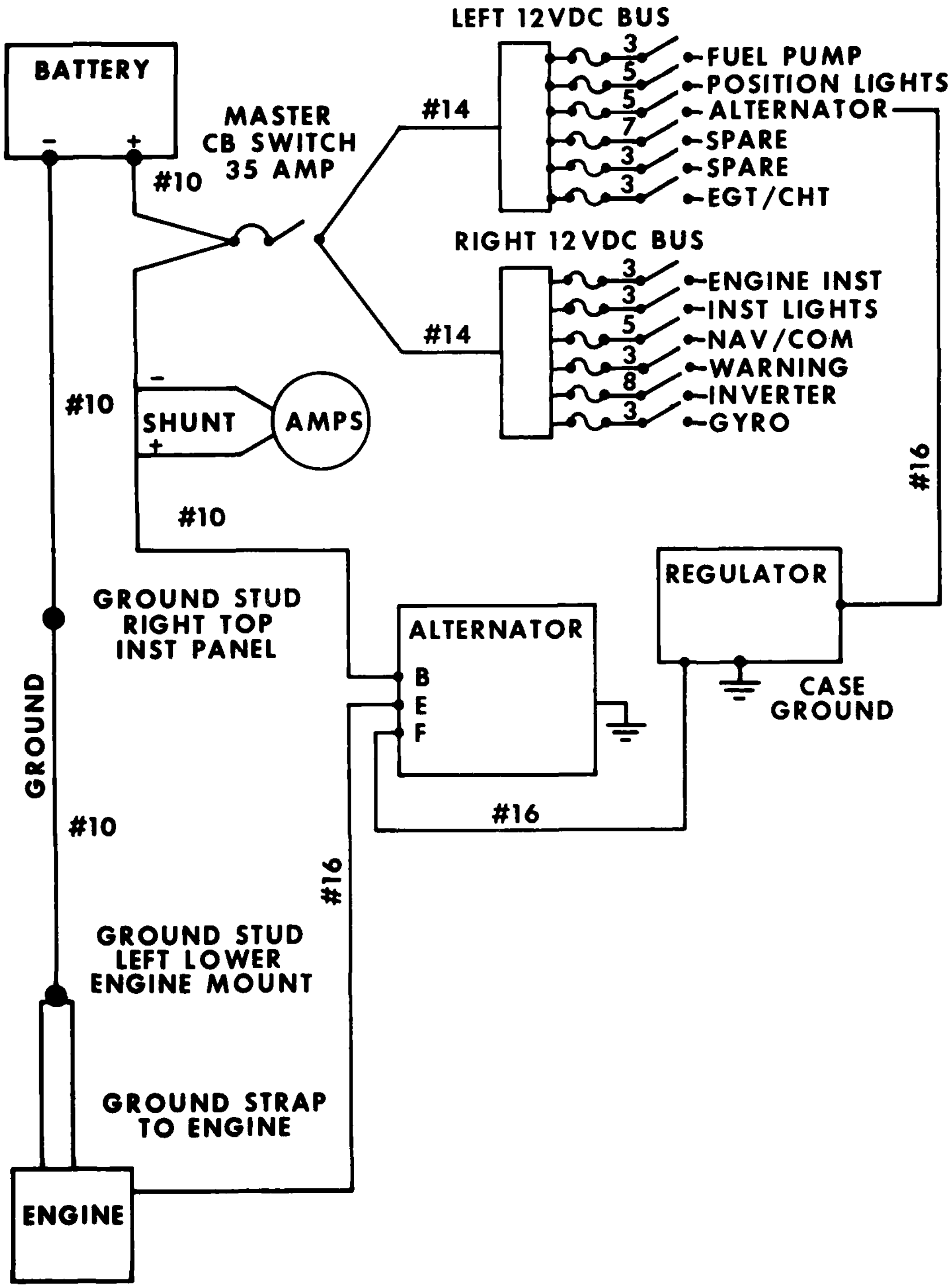


Figure 6. Electrical System LONG-EZE N 1253

COCKPIT

Seating

14. Tandem, semi-supine (reclining approximately 40 degrees to the vertical) cockpit seating is provided in the LONG-EZ.

Controls

15. Full flight controls are provided in the front cockpit only. A side-arm control stick is positioned on the right side console with throttle, mixture, carburetor heat, pitch trim and speed-brake controls on the left console. The nose gear crank actuation handle is located in the center of the pilot's instrument panel. A control stick is located in the rear seat area to allow passengers to land should the pilot become incapacitated. The rear stick is removable to allow increased baggage room. The rear seat does not have rudder pedals, due to the awkward foot position afforded the rear seat occupant. Neither power management nor landing gear actuation controls are provided in the aft cockpit.

BAGGAGE

16. The inboard portion of the large wing strakes are used as baggage areas, accessible from the front and rear cockpits. Small baggage, maps and navigation instruments may be stored in the front cockpit in two areas beneath the thigh support and in the pilot headrest/map case/rollover structure. Baggage areas inside the center-section spar and behind the rear seat provide additional stowage.

ENVIRONMENTAL CONTROL

17. Due to the insulated fuselage structure and long plexiglass canopy, the LONG-EZ is designed to maintain about 60°F inside temperature with an outside temperature of 10°F (vent closed, sun shining). A cabin air vent located in the front of the canopy structure is designed to provide ram air for cabin ventilation.

WARNING SYSTEMS

18. In addition to the landing gear warning system (para 5) the airplane is equipped with an electrical buzzer which warns the pilot not to take off with the canopy unlocked. Also, a canopy

safety latch is installed as a back-up to catch the canopy if the pilot forgets to lock it for takeoff.

FLIGHT CONTROLS

General

19. The LONG-EZ is equipped with a reversible type mechanical flight control system actuated through the side-arm control stick (pitch and roll) in the front and aft cockpits and rudder pedals (yaw) in the front cockpit (para 17). The cockpit flight controls are connected to the flight control surfaces through a series of push-pull tubes, bellcranks, and cables.

SIDE STICK CONTROLLER

20. Pitch is controlled by the side stick controller by a full-span canard slotted elevator. Roll is controlled by conventional ailerons on the trailing edge of the rear wing. A detailed view is shown in figure 7.

RUDDERS

21. The rudders, located on the winglets at the wing tips, operate outboard only, providing two totally independent systems (fig. 4). The rudders may be used singularly for yaw control or can be deployed together as a mild speed brake. The rudder pedals do not provide nose wheel steering. Steering is accomplished with main gear braking actuated through full rudder deflection and full castering nose wheel.

TRIM SYSTEMS

22. Cockpit-adjustable trim is provided for pitch and roll only. Yaw/rudder trim is ground adjustable only. Pitch and roll trim are bungee/spring systems. There are no adjustable aerodynamic trim tabs. The pitch trim handle is located on the left console inboard of the landing airbrake handle. The aileron trim handle is located on the right console. The system is designed to allow the pilot to safely override any trim setting even if it is stuck in an extreme position. The pitch trim is designed to trim to hands-off flight from stall to maximum speed. This feature is provided to allow the pilot to land the aircraft using the pitch trim, rudders, and throttle only in the event a failure/disconnect occurs in the normal control stick.

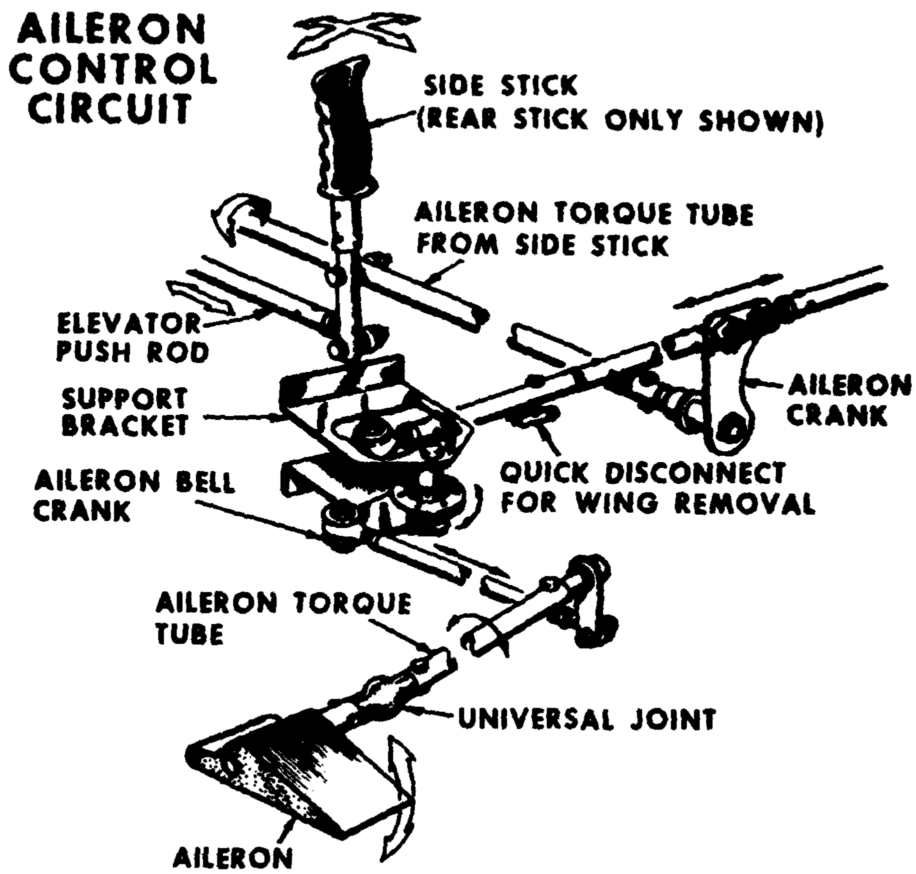


Figure 7. Aileron Control Circuit

Limit Control Travel

23. Primary airfoil and flight control rigging with maximum limits are presented in tables 1 through 3 and figure 8.

Table 1. Principal Dimensions

Height	
Left winglet tip	93.2 in.
Right winglet tip	93.9 in.
Length (nose to spinner)	183.1 in.
Wing span	315 in.
Canard span	142.1 in.
GROUND CLEARANCES	
Left Wing tips	37.1 in.
Right Winglets	37.0 in.
PROPELLER	
Horizontal	45.3 in.
Vertical	16.5 in.
CABIN	
Length	
Front	70 in.
Rear	54 in.
Width	
Front	36 in.
Rear	35 in.
Height	
Front	36 in.
Rear	35 in.

Table 2. Airfoil Geometry

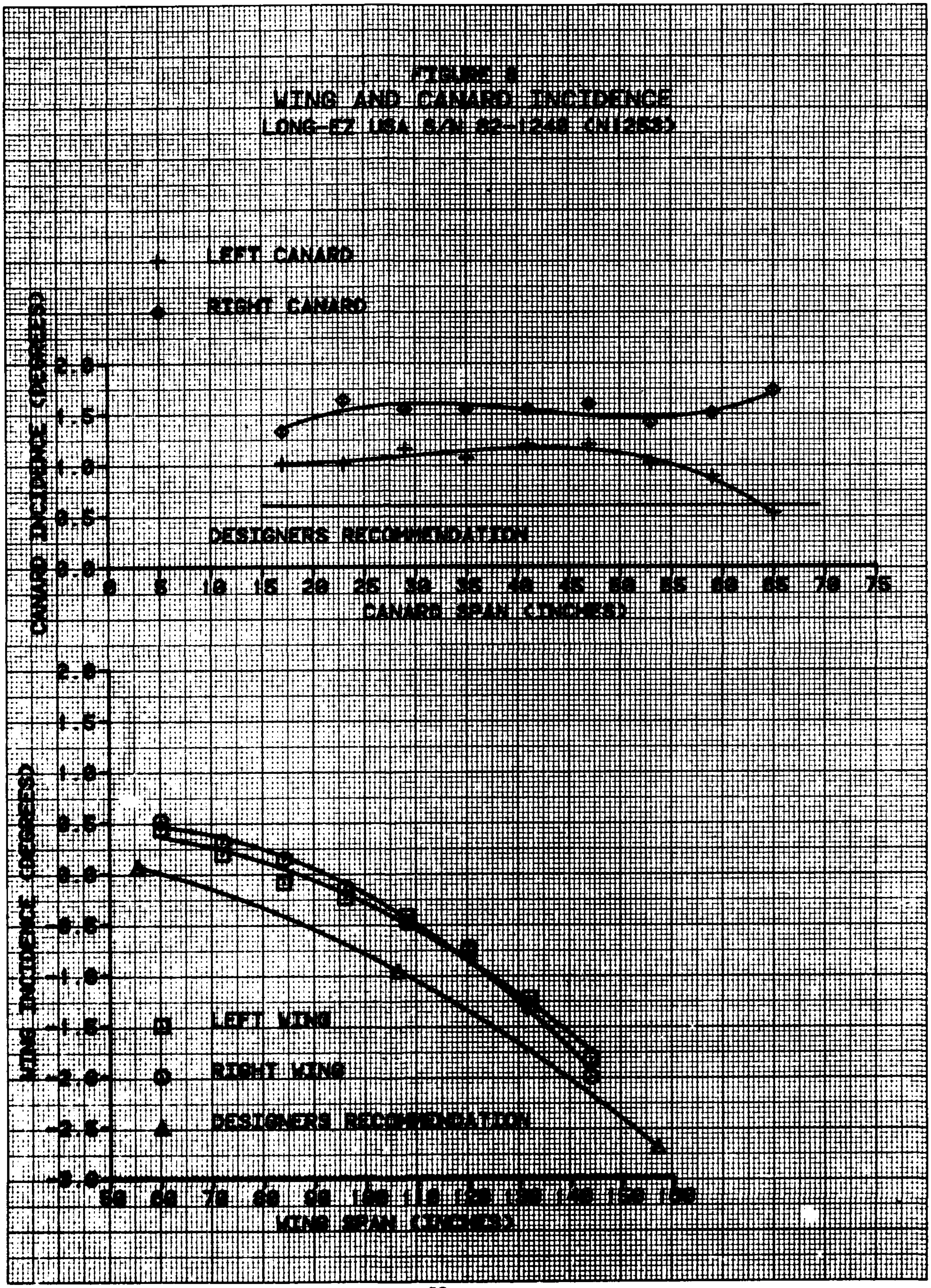
Airfoil	Average Measured	Tolerance
WING (Eppler 1230)		
Incidence	L 0.51° R 0.48°	±0.5°
Sweep	L 25.0° R 24.3°	±1.1° of each other
Chord (BL 106.25)	L 31.50 in. R 31.15 in.	31.35 in.
Thickness (% chord @ BL 108)	L 15.9% R 15.8%	-----
Dihedral	L -1.6° R -1.4°	-----
Leading Edge Fuselage station location Root Tip	114.2 156.5	FS 113.9±0.3 FS 156.0±1.0"
CANARD		
Incidence	L 0.87° R 1.5°	0.6°±0.3
Sweep	None	None
Chord	13 in.	-----
Thickness	19% at 41% M.A.C.	-----
Dihedral	L -0.18° R -0.15°	0
Leading edge fuselage station location	18.3	FS 18.6±0.3"
WINGLET		
Mean aerodynamic Chord	20.3 in. upper 26.0 in. lower	-----
Thickness	12% M.A.C. upper 11% M.A.C. lower	-----
@ M.A.C. Span	L 56.3 in. R 56.9 in.	-----

Table 3. Control System Rigging

Control	Average Measured	Tolerance
ELEVATOR		
Left		
Weight	3.7 lb	Less than 3.9 lb
Mass balance	16° TEU	12-26° TEU
Travel		
Trailing edge up	19.1°	20°±2° TEU
Trailing edge down	18.2°	22°±2° TED
Free play (static)	0.04 in.	-----
Right		
Weight	3.5 lb	Less than 3.6 lb
Mass balance	22.0°TEU	12-25° TEU
Travel		
Trailing edge up	18.5°	20°+2°TEU
Trailing edge down	23.9°	22±2° TED
Free play (static)	0.04 in.	-----
AILERONS		
Left		
Weight	5.4	-----
Mass balance	Bottom surface 2.7° TEU	Bottom or top surface level
Travel		
Trailing edge up	1.87 in.	2.1 in.±0.3in. TED
Trailing edge down	2.0 in.	2.1 in.±0.3in. TED
Free play (static)	0.1 in.	-----
Right		
Weight	5.5 lb	-----
Mass balance	0.1° TEU	Bottom or top surface level
Travel		
Trailing edge up	1.87 in.	2.1 in.±0.3in. TEU
Trailing edge down	2.0 in.	2.1 in.±0.3in. TED
Free play (static)	0.2 in. TEU center 0.02 in. TED	
RUDDERS		
Left deflection	5.9 in.	6 in.±0.5 in.

Table 3. Control System Rigging (cont)

Control	Average Measured	Tolerance
Static force (at full deflection)	36.6 lb	N/A
Right deflection	5.75 in.	6 in. ± 0.5 in.
Static force (at full deflection)	27.3 lb	N/A
LANDING GEAR		
<u>Main</u>		
Toe-In		
Left	0.29°	
Right	0.21°	0.25-0.5° per side
Caster angle	4.0° left 4.9° right	-----
Tread (between center line of main wheels)	62.15 in. (empty)	-----
Fuselage station	109.7	FS 110.5±1
Size	500 x 5	500 x 5
Pressure	40	35-40 psi
<u>Nose</u>		
Castering Friction	3.1 lb TER 3.7 lb TEL	2-4 lb
Size	2.80/2.50	Standard
Pressure	40 psi	40-45 psi
Gear Actuation cycle	18.3 lb extend	10 lb load
Gear warning	0.4 in.	last 0.1 in.
Wheel base (nose to main gear center line)	92.1 in. (empty)	-----
PROPELLER		
Diameter	62 in.	62 in.
Pitch	66°	66°
Track	0.1 in.	±0.1 in.
Landing airbrake actuation load	39 lb	40 lb


WING AND CANARD INCIDENCE
LEFT CANARD
RIGHT CANARD
DESIGNERS RECOMMENDATION
CANARD INCIDENCE (DEGREES)
CANARD SPAN (INCHES)
LEFT WING
RIGHT WING
DESIGNERS RECOMMENDATION
WING INCIDENCE (DEGREES)
WING SPAN (INCHES)

APPENDIX C. INSTRUMENTATION

1. An airborne data telemetry system was installed and maintained by USAAEFA. The system utilized pulse code modulation (PCM) encoding and incorporated a self-contained 24 VDC power source with sufficient capacity for a minimum of one hour test duration. The data was transmitted to the real Time Data Acquisition and Processing (RDAPS) for processing and storage.

2. Instrumentation and related special equipment installed are presented below. Photos 1 and 2 show the cockpit instrument panel, auxillary instrument panel controls, and the cockpit location and installation of the airborne data telemetry system.

<u>Pilot Station</u> (Front cockpit display)

Sensitive airspeed
Sensitive manifold pressure
Sensitive normal acceleration
Calibrated altimeter
Calibrated engine speed
Cyclinder head temperatures (4)
Exhaust gas temperatures (4)

<u>Airborne Data Telemetry System</u>

Pilot event
Airspeed
Altitude
Pitch attitude
Roll attitude
Pitch rate
Roll rate
Yaw rate
Normal acceleration (CG)
Longitudinal control position
Lateral control position
Rudder pedal position left
Rudder pedal position right
Fuel flow
Fuel totalizer
Outside air temperature
Vertical vibration left wing spar (FS 110 BL 22)
Vertical Aileron Vibration (left and right located at inboard trailing edge BL 55.5)

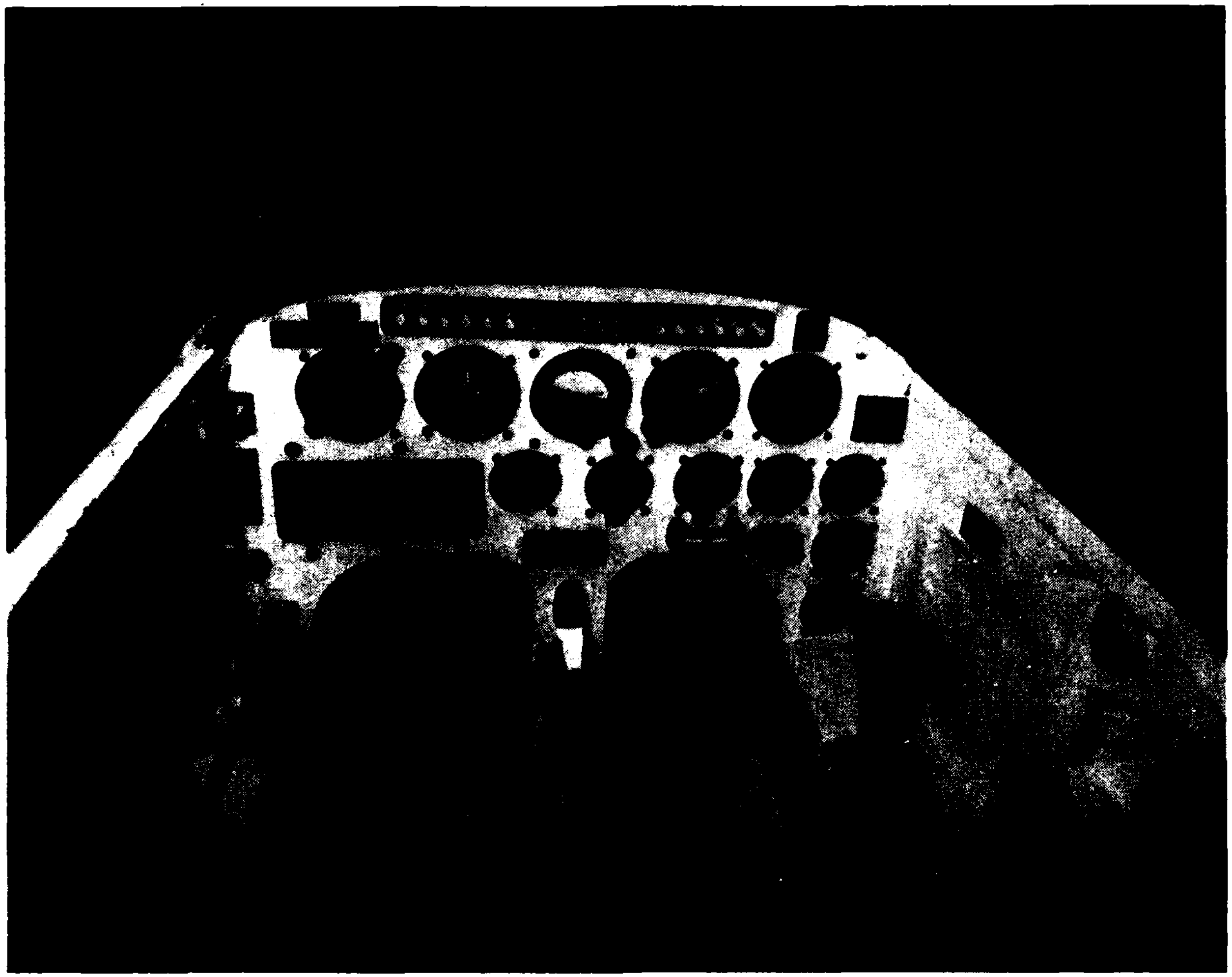


Photo 1. Forward Cockpit

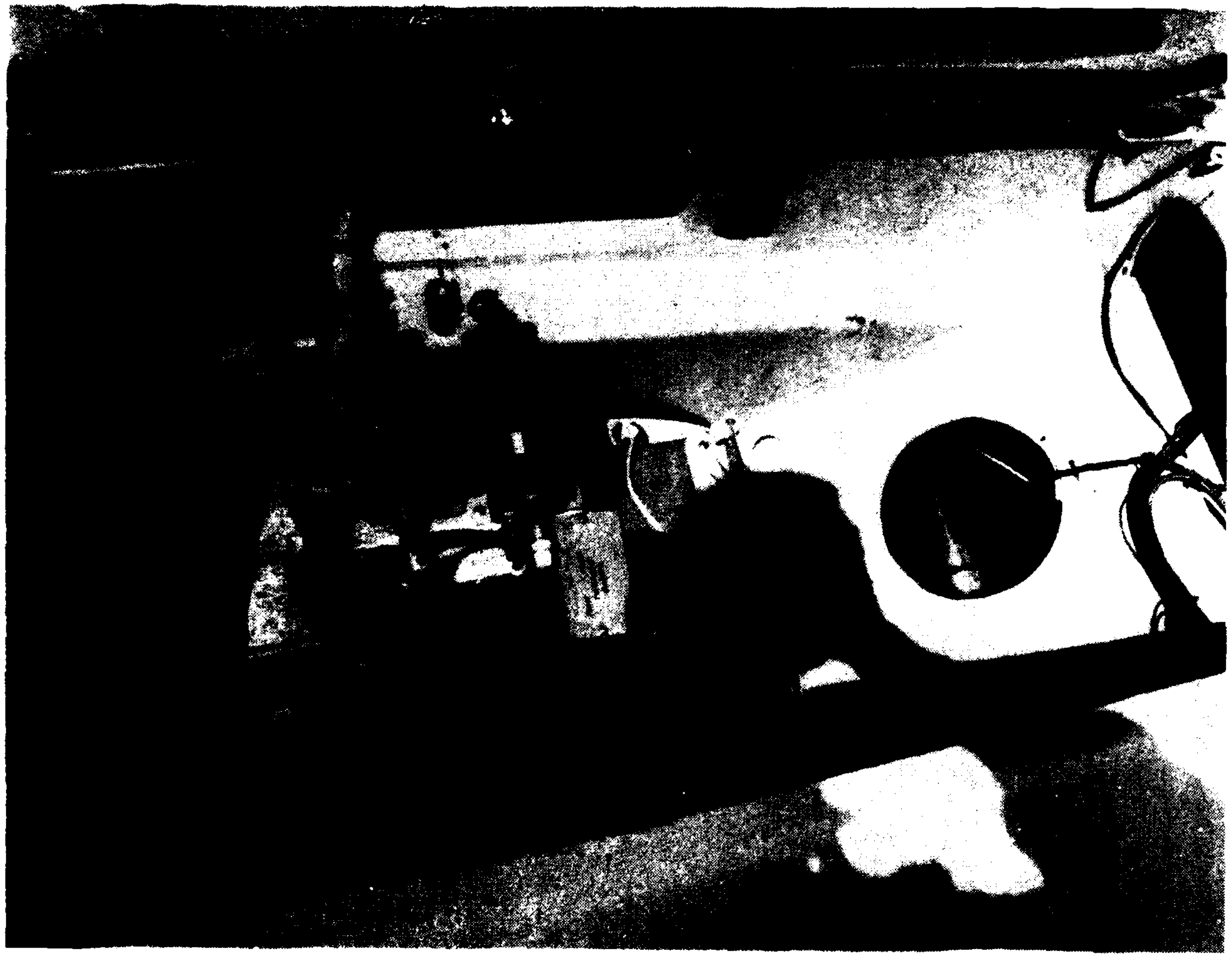


Photo 2. Instrumentation Aft Cockpit

APPENDIX D. TEST TECHNIQUES AND DATA ANALYSIS METHODS

GENERAL

1. This appendix contains some of the data reduction techniques and analysis methods used to evaluate the LONG-EZ aircraft. Topics discussed include glide, level flight, takeoff and landing performance, airspeed calibration, and weight and balance.

GLIDE, LEVEL FLIGHT, AND CLIMB PERFORMANCE

2. The propeller stopped glide method was used to define the drag of the LONG-EZ aircraft in the cruise and landing configurations. The method involved obtaining flight data while the aircraft was stabilized in a constant-airspeed descent with the engine shut down and propeller stopped. Parameters measured included airspeed, pressure altitude, outside air temperature, gross weight, and elapsed time. The airspeed range from $1.1V_S$ to maximum operating airspeed with the propeller stopped was investigated for a target pressure altitude (H_P) band of 6000 to 10,000 feet. The technique used to develop the baseline-drag equation is shown below.

$$L = W \cos \theta \tag{1}$$

$$D = T + W \sin \theta \tag{2}$$

$$DV_T = TV_t + WV_t \sin \theta \tag{3}$$

$$-V_T \sin \theta = \frac{dh}{dt} = \frac{TV_t - DV_t}{W} \tag{4}$$

Where:

L = Lift force (lb)

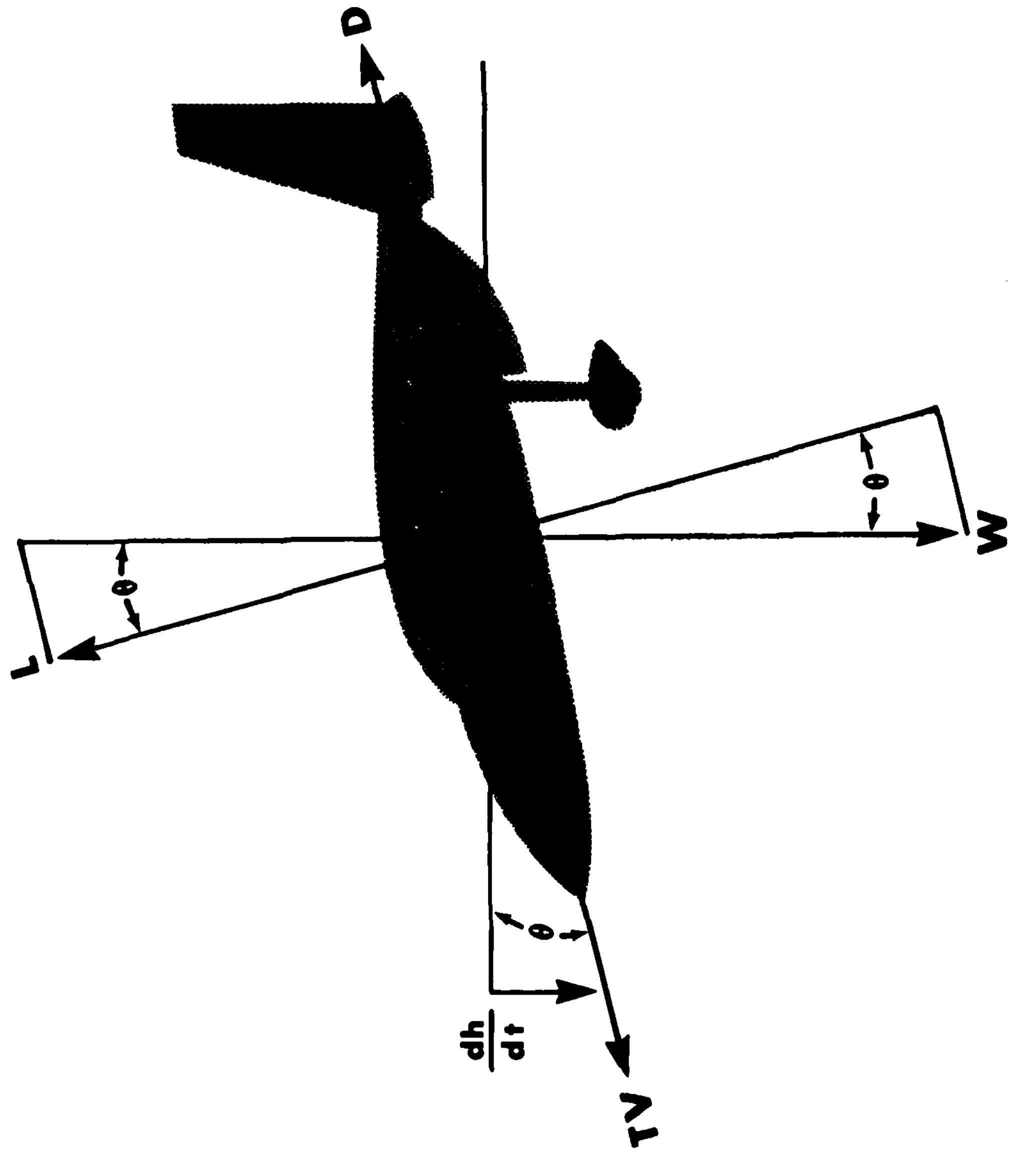
W = Aircraft gross weight (lb)

θ = Descent angle (deg) = $\sin^{-1} \dfrac{dh_P/dt}{V_T}$

T = Net thrust (lb) = zero with propeller stopped.

D = Drag force (lb)

V_t = Aircraft true airspeed on flight path (ft/sec)


D
W
L
θ
θ
θ
dh/dt
TV

$$\frac{dh}{dt} = \text{Tapeline rate of descent (ft/sec)} \; \frac{d_{H_p}}{dt} \; \frac{T_{a_t}}{T_{a_s}}$$

$\frac{dHp}{dt}$ is measured

Considering the drag and lift force equations and applying power-off glide conditions, the following non-dimensional relationships can be developed:

$$C_D = \frac{D}{qs} \tag{5}$$

$$C_D = \frac{W \sin \theta}{qs} \tag{6}$$

$$C_L = \frac{L}{qs} \tag{7}$$

$$C_L = \frac{W \cos \theta}{qs} \tag{8}$$

Where:

C_D = *Coefficient of drag*

$q = 1/2\ \rho\ V_T^2$ (lb/ft^2) dynamic pressure

S = Total wing area (ft^2)

C_L = Coefficient of lift

ρ = Air density ($slug/ft^3$)

The drag equation (C_D) was then developed by plotting C_D versus C_L^2 and fitting a first-order equation to the test points.

$$C_D = C_{DO} + \frac{\Delta C_D}{\Delta C_L^2} C_L^2$$

Coefficient of drag of the stopped propeller was determined from methods described in Hoerner's Fluid-Dynamic Drag (ref 11, app A) and the following equation.

$$C_{D_{prop}} = 0.1 + \cos^2 R$$

Where:

$C_{D_{prop}}$ = Coefficient of drag of the propeller blade

R = blade angle at 0.7 radius

The drag of the stopped propeller is then calculated from the following equation.

$$Drag_{prop} = C_{D_{prop}} \times q \times S_{blade}$$

Where:

$Drag_{prop}$ = Drag of the stopped propeller

S_{blade} = The developed blade area which includes blockage effects of the fuselage estimated to be 0.9 ft^2 for the Ted's propeller)

3. Level flight performance tests were conducted using the constant pressure altitude method. The aircraft was stabilized and trimmed at incremental airspeeds from minimum airspeed to V_H while maintaining a constant pressure altitude. Test brake horsepower was determined from the Lycoming engine performance data chart (fig. 53, app E) and no corrections were made for inlet losses. Horsepower was corrected to standard altitude and weight by the following equation.

$$BHP_s = BHP_t \left(\frac{\dfrac{7.6885 \times 10^{-4}(W_s^2 - W_t^2) \quad T_{a_s}}{\eta_p \quad P_a \quad b^2 \quad M \quad e}}{\dfrac{T_{a_s}}{T_{a_t}}} \right)$$

Where:

T_{a_s} = standard day temperature at the pressure altitude under consideration (Degrees Kelvin)

T_{a_t} = test ambient temperature (Degrees Kelvin)

BHP_t = Test Brake Horsepower

BHP_s = Standard Brake Horsepower

P_a = Atmospheric Pressure (In-Hg)

b = Wing Span (feet)

M = Mach Number

W_s = Standard Gross Weight (pounds)

e = Airplane Efficiency Factor

W_t = Test Gross Weight (pounds)

η_p = Propulsion Efficiency

True airspeed is corrected to standard day true airspeed with the following equation.

$$V_{T_s} = M \sqrt{T_{a_s}} \times 38.944$$

Where:

V_{T_s} = Standard Day True Airspeed (knots)

M = Test Mach Number

T_{a_s} = Standard day temperature (Degrees Kelvin)

Propulsion efficiency was determined from the following equation.

$$\eta_p = \frac{THP}{BHP_S}$$

where:

THP = Thrust horsepower

Coefficient of power was determined from the following equation.

$$C_p = .5 \frac{BHP_S/1000}{\sigma\ (RPM/1000)^3 (D/10)^5}$$

Where:

C_P = coefficient of power

σ = density ratio

RPM = propeller speed

D = propeller diameter (feet)

The advance ratio was determined from the following equation.

$$J = \frac{88V_T}{RPM\ D}$$

4. The specific range (NAMPP) data were derived from the level flight power required and fuel flow. The NAMPP curves presented in the level flight performance plots were obtained from power and airspeed for level flight and fuel flow data in the Lycoming engine detailed specification. The following equation was used for determination of NAMPP.

$$NAMPP = \frac{V_T}{W_F}$$

Where:

V_T = True airspeed
W_F = Fuel flow (lb/hr)

5. Propulsive efficiency was generalized using methods described in Perkins and Hage (ref 12, app A) and the data were plotted as propulsive efficiency versus the ratio of advance ratio to the cube root of the power coefficient. Thrust horsepower was determined from the Glide Drag Polar and the following equation:

$$THP = \frac{C_D \rho V_T^3 S}{1100}$$

6. Dynamic stability characteristics were evaluated to determine the damping ratios and damped natural frequencies. They were derived for all conditions tested by the transient peak ratio.

7. The two transient peak ratio (TPR) methods used for lightly damped, moderately damped, and unstable aircraft motion are the "half-amplitude" and the "double-amplitude" methods. The range of damping ratios determined by these methods is from -0.5 to +0.5. The damped natural frequencies were obtained by direct measurement of the period of oscillation and computed by the formula:

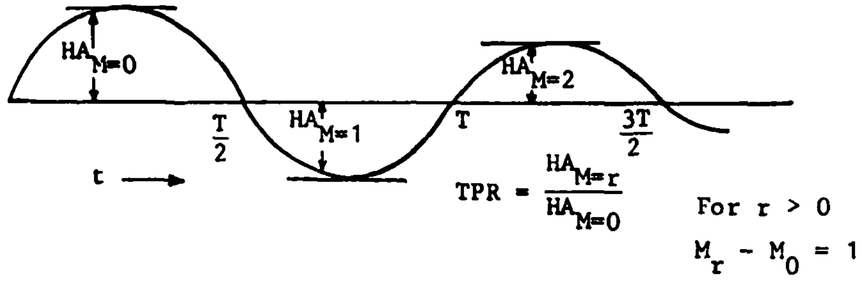
$$\omega_{damped} = \frac{1}{\tau}$$

Where:

ω_{damped} = Damped natural frequency (cycles/sec)

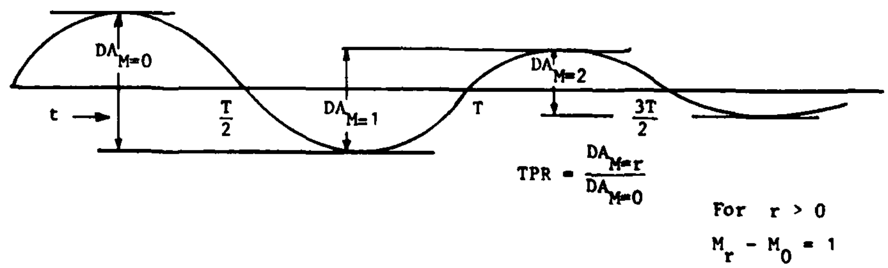
τ = The period of one oscillation from one peak to the next peak (sec)

The half-amplitude method requires that the initial steady-state value be known and that the steady state be constant. Once the steady-state value has been determined, the half-amplitudes are obtained by measuring the distance from the steady state to the maximum and minimum points of response.



Half-Amplitude Method

The double amplitude method also requires that the steady state be a constant, but if the double amplitudes are measured as shown below, the transient peak ratio can be obtained without having to establish the steady state or trim value of response.



Double-Amplitude Method

8. Roll mode time constant was determined as the time to achieve 63 percent of steady state roll rate.

AIRSPEED CALIBRATION

9. The test boom and ship's standard pitot-static system were calibrated using the pace aircraft method to determine the airspeed position error (fig. 52, app F). Calibrated airspeed (V_{cal}) was obtained by correcting indicated airspeed (V_i) for instrument error (ΔV_{ic}) and position error (ΔV_{pc}).

$$V_{cal} = V_i + \Delta V_{ic} + V_{pc} \qquad (17)$$

10. Equivalent airspeed (V_e) was used to reduce the flight test data, as it is a direct measure of the free stream dynamic pressure (q).

$$V_e = V_{cal} + \Delta V_c$$

Where:

ΔV_c is the compressibility correction, $q = 0.00339 V_e^2$

11. True airspeeds (V_T) were determined from the test altitude air density ratio (σ) and equivalent airspeed, as follows:

$$V_T = \frac{V_e}{\sqrt{\sigma}}$$

Weight and Balance

12. Prior to the start of flight tests, the aircraft was weighed to determine weight, and longitudinal and lateral center-of-gravity locations. The aircraft was be weighed in the following configurations:

a. Full oil, trapped fuel, and no crew.

b. Full oil, full fuel, and no crew.

c. Full oil, full fuel, and pilot.

d. Full oil, full fuel, ballast, instrumentation, and pilot.

Fuel Cell Calibration

13. An external fuel quantity sight gauge (manometer-type) was installed for each fuel tank. The ships fuel gauges and the external gauge were calibrated by adding fuel in 1 gallon increments in each tank to 5 gallons and 5 gallon increments, thereafter, until full and reweighing the aircraft after each increment. Trapped fuel was determined by draining each tank with the aircraft leveled.

Rigging Check

14. Mechanical rigging of engine and flight controls was checked for compliance with applicable RAF and Lycoming documents. All rigging discrepancies were resolved prior to the start of tests.

DEFINITIONS

15. Results were categorized as deficiencies or shortcomings in accordance with the following definitions.

Deficiency

16. A defect or malfunction discovered during the life cycle of an item of equipment that constitutes a safety hazard to personnel; will result in serious damage to the equipment if operation is continued, or indicates improper design or other cause of an item or part, which seriously impairs the equipment's operational capability. A deficiency normally disables or immobilizes the equipment; and if occurring during test phases, will serve as a bar to type classification action.

Shortcoming

17. An imperfection or malfuntion occurring during the life cycle of equipment, which must be reported and which should be corrected to increase efficiency and to render the equipment completely serviceable. It will not cause an immediate breakdown, jeopardize safe operation, or materially reduce the usability of the material or end product. If occurring during test phases, the shortcoming should be corrected if it can be done without unduly complicating the item or inducing another undesirable characteristic such as increase cost, weight, etc.

18. A Handling Qualities Rating Scale was used to augment pilot comments relative to handling qualities. This scale is presented in figure 1.

19. A Vibration Rating Scale (VRS) was used to qualitatively assess airframe vibrations. This scale is presented in figure 2.

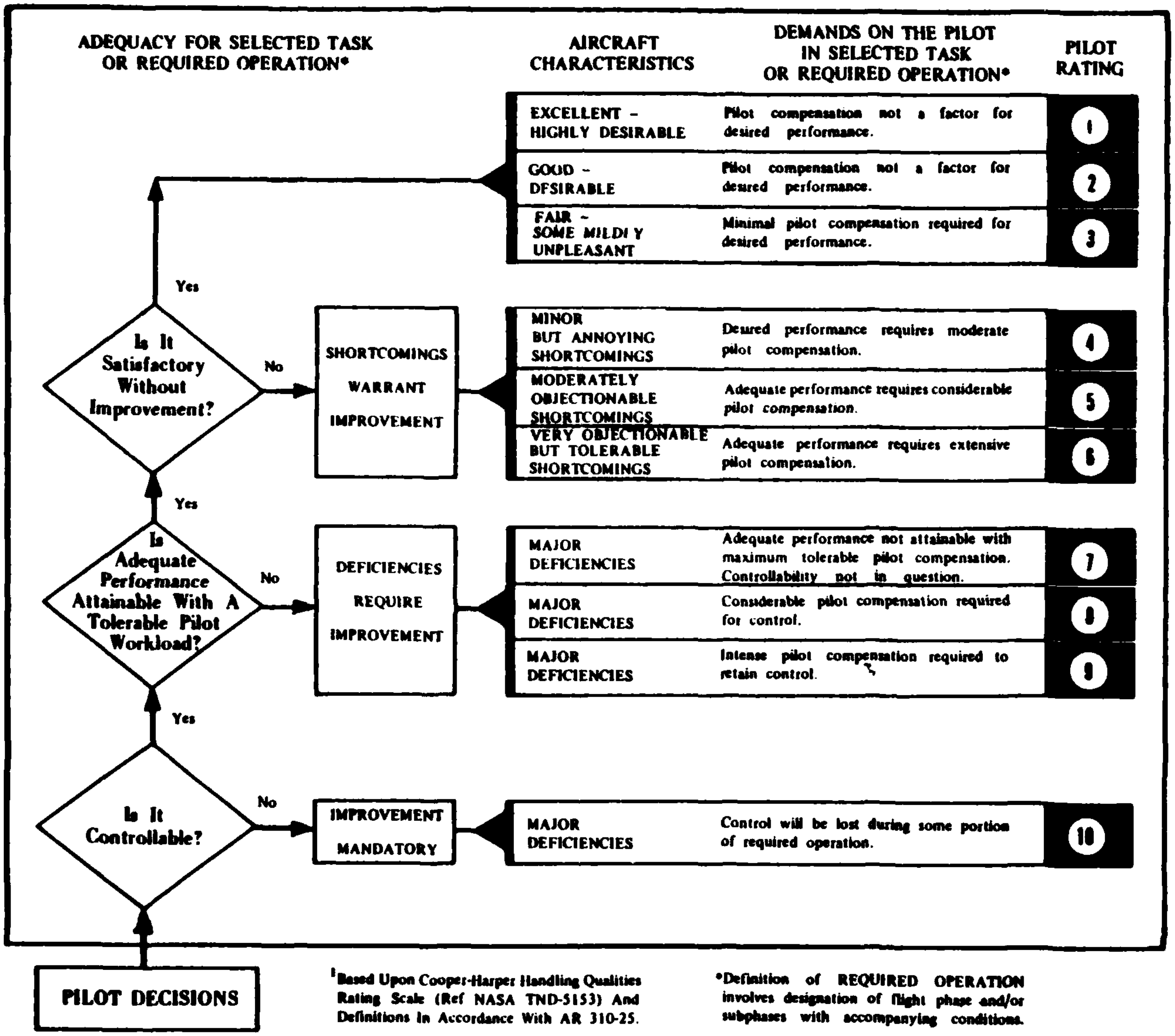
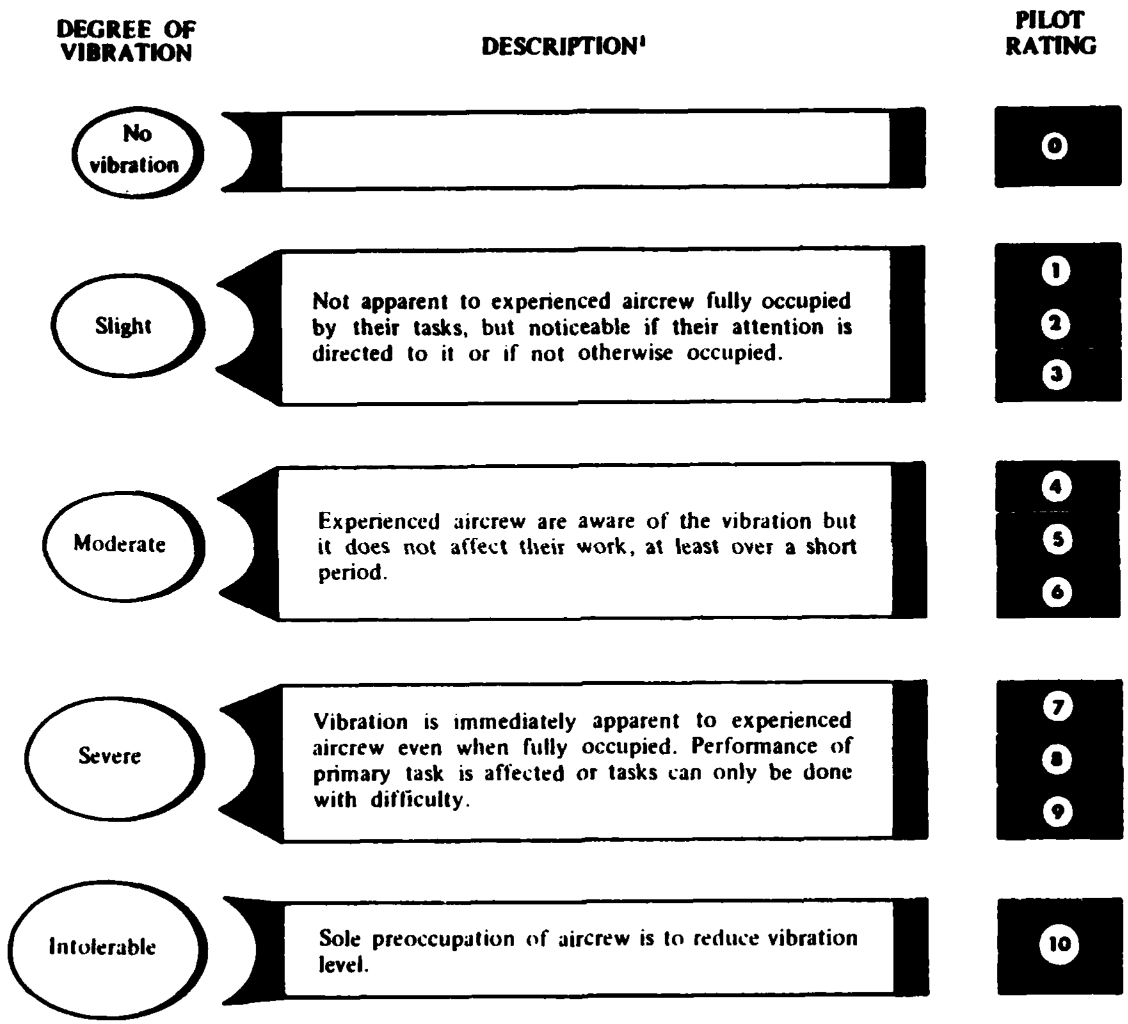


Figure 1. Handling Qualities Rating Scale



[1] Based upon the Subjective Vibration Assessment Scale developed by the Aeroplane and Armament Experimental Establishment, Boscombe Down, England.

Figure 2. Vibration Rating Scale

Table 1. Pilots Anthropometric Measurements

Body Measurements	Pilot 1		Pilot 2	
	Measurement	Percentile (%)	Measurement	Percentile (%)
Weight (lb)	165	19	163	17
Height (in.)	69	36	64.1	1
Acrominal Shoulder Height (seated) (in.)	25	87	24	60
Eye Height (seated) (in.)	32.6	81	31.2	40
Seated Height (in.)	37.5	84	34.5	9
Functional Reach (in.)	32.6	72	29.8	11
Buttock Knee (in.)	22.8	9	22.3	4
Knee height (in.)	21.8	47	19.3	1
Popliteal Height (in.)	16.5	18	15.6	3
Shoulder Breadth (normal) (in.)	19.3	74	17.9	50

APPENDIX E. TEST DATA

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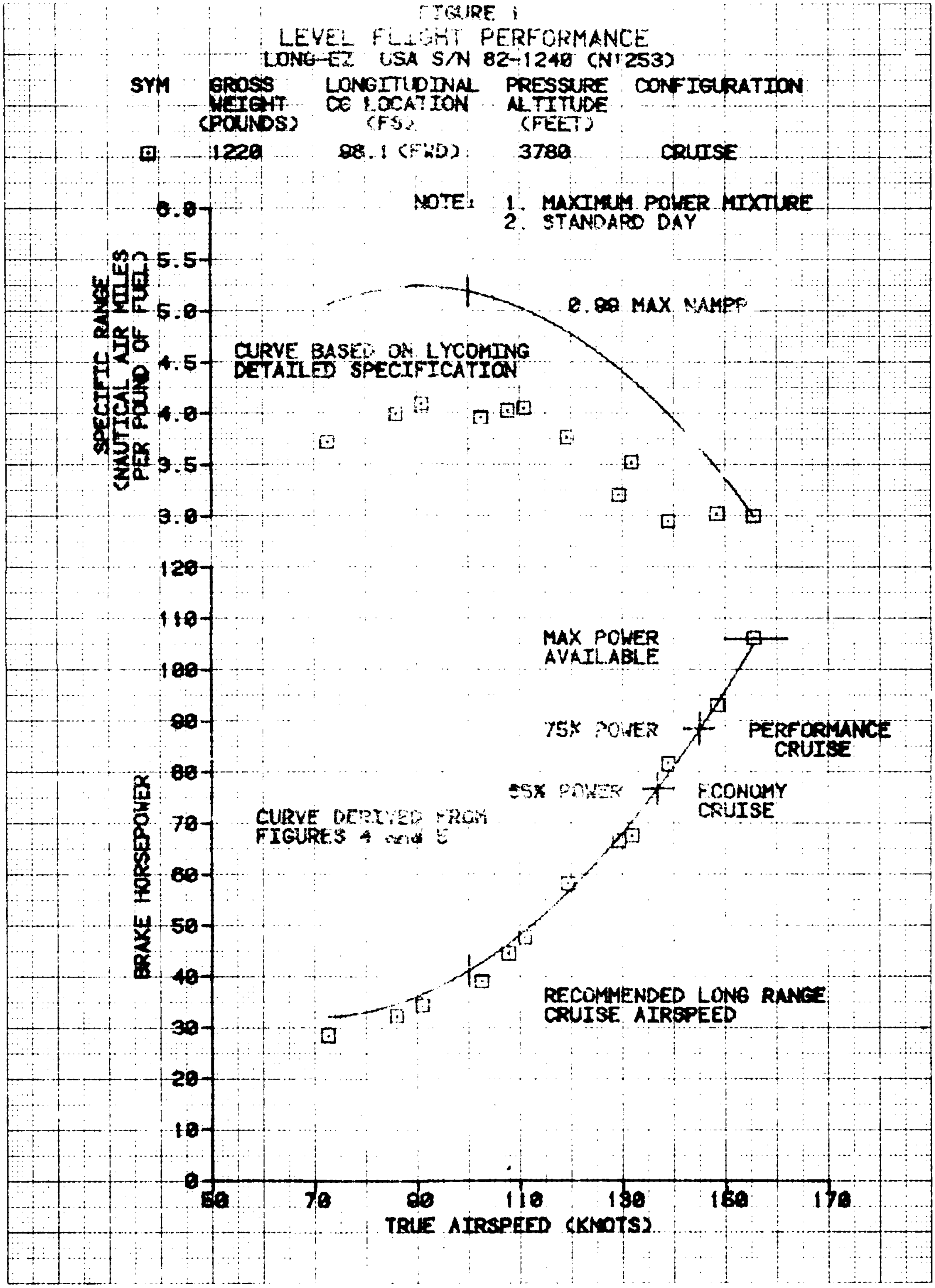
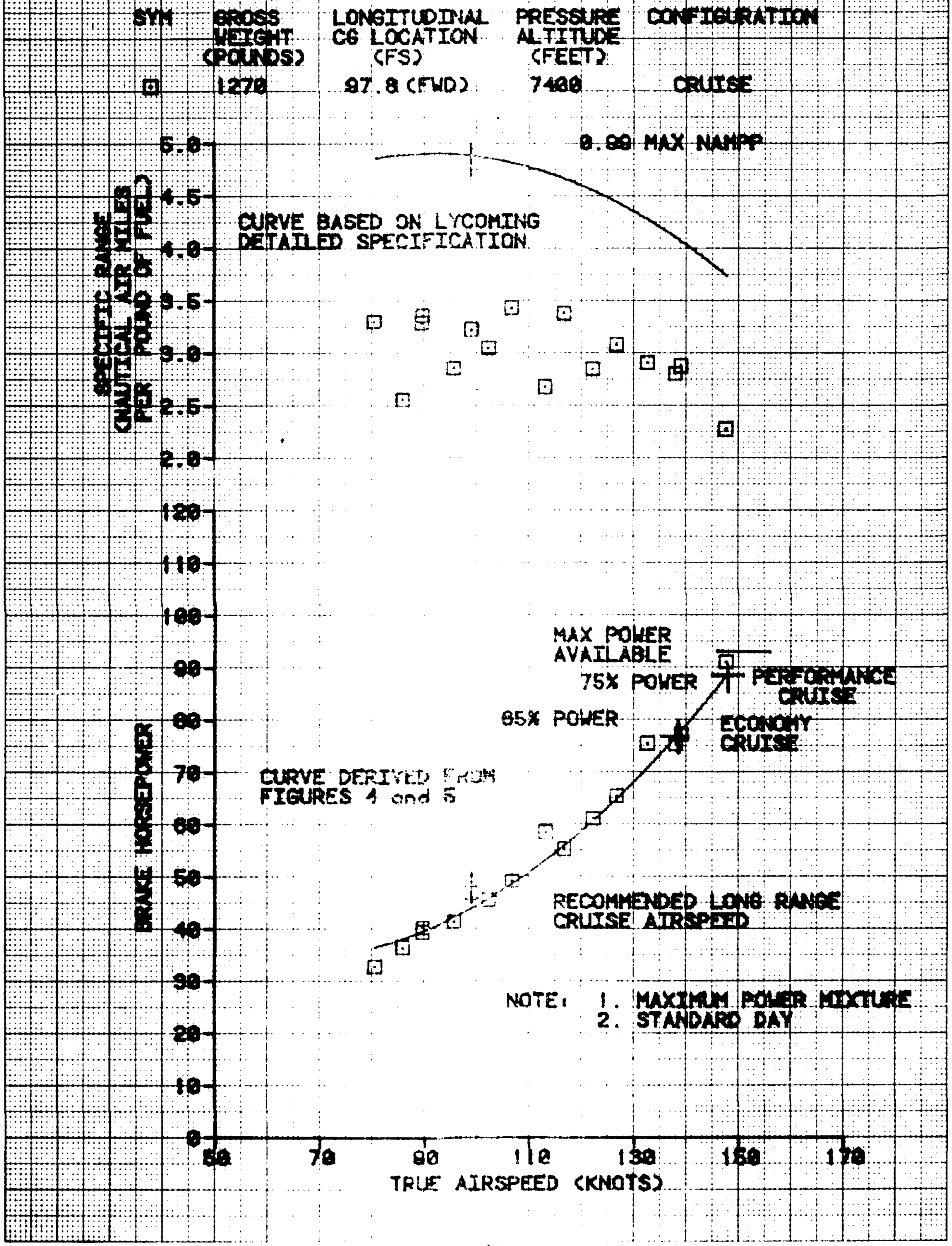


FIGURE 1
LEVEL FLIGHT PERFORMANCE
LONG-EZ USA S/N 82-1240 (N1253)
SYM
GROSS WEIGHT (POUNDS)
LONGITUDINAL CG LOCATION (FS)
PRESSURE ALTITUDE (FEET)
CONFIGURATION
1220
98.1 (FWD)
3780
CRUISE
NOTE: 1. MAXIMUM POWER MIXTURE
2. STANDARD DAY
SPECIFIC RANGE (NAUTICAL AIR MILES PER POUND OF FUEL)
0.99 MAX NAMPP
CURVE BASED ON LYCOMING DETAILED SPECIFICATION
BRAKE HORSEPOWER
MAX POWER AVAILABLE
75% POWER
PERFORMANCE CRUISE
65% POWER
ECONOMY CRUISE
CURVE DERIVED FROM FIGURES 4 and 5
RECOMMENDED LONG RANGE CRUISE AIRSPEED
TRUE AIRSPEED (KNOTS)

FIGURE 2

LEVEL FLIGHT PERFORMANCE

LONG-EZ USA S/N 82-1240 (N1253)



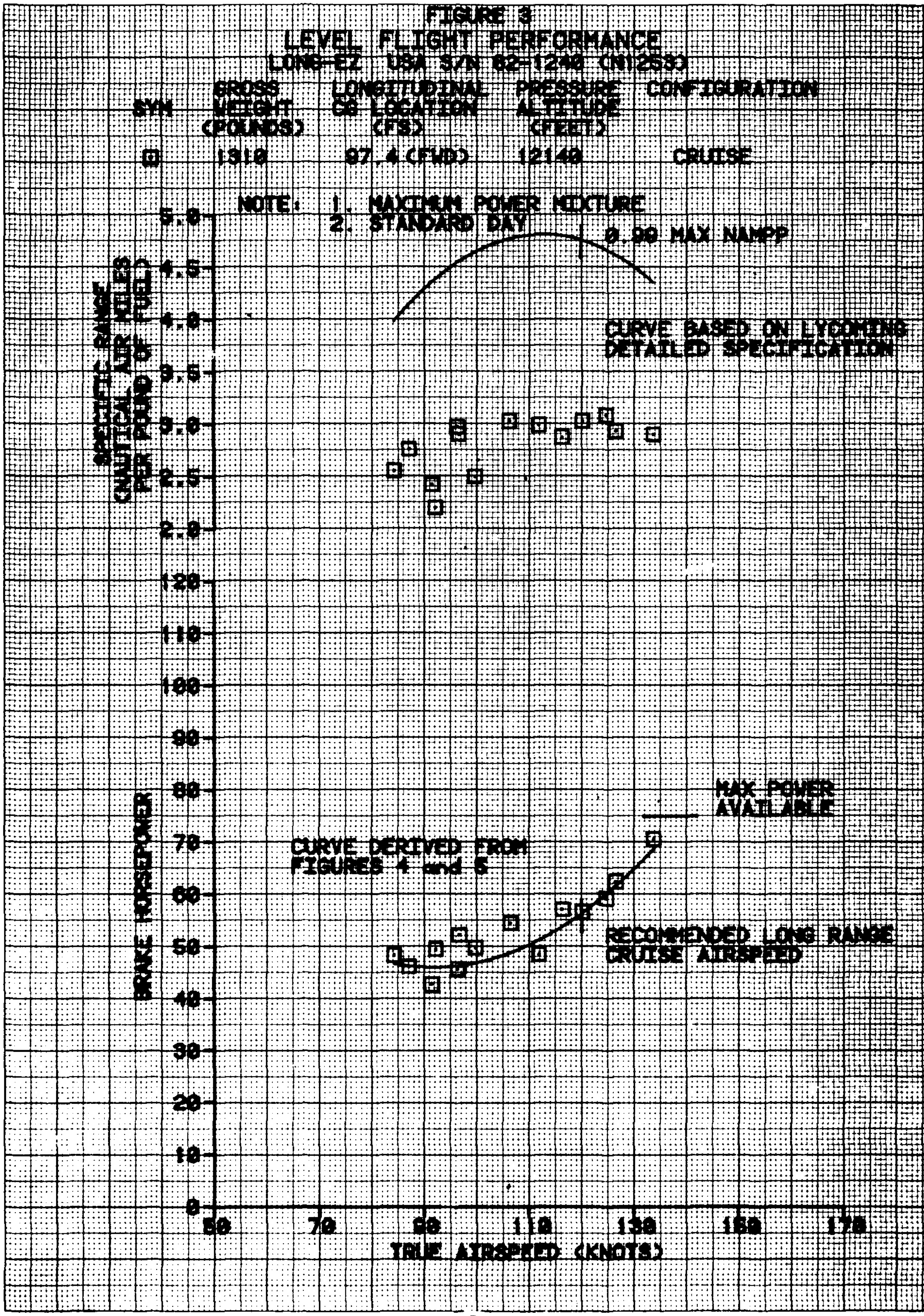
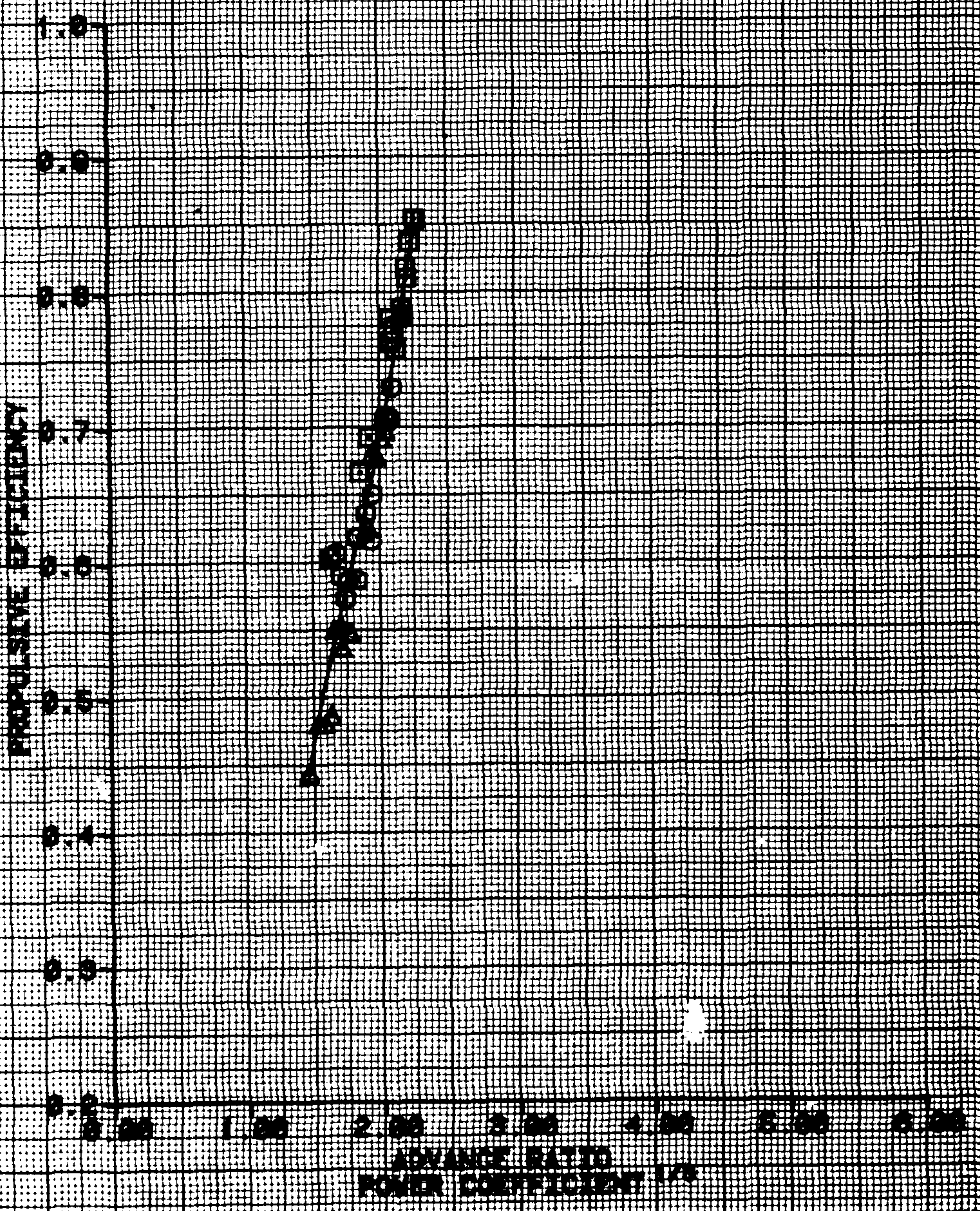


FIGURE 3
LEVEL FLIGHT PERFORMANCE
LONG-EZ USA S/N 82-1240 (N12530)
SYM
GROSS WEIGHT (POUNDS)
LONGITUDINAL CG LOCATION (FS)
PRESSURE ALTITUDE (FEET)
CONFIGURATION
1310
97.4 (FWD)
12140
CRUISE
NOTE: 1. MAXIMUM POWER MIXTURE
2. STANDARD DAY
0.99 MAX NAMPP
CURVE BASED ON LYCOMING DETAILED SPECIFICATION
SPECIFIC RANGE (NAUTICAL AIR MILES PER POUND OF FUEL)
MAX POWER AVAILABLE
CURVE DERIVED FROM FIGURES 4 and 5
RECOMMENDED LONG RANGE CRUISE AIRSPEED
BRAKE HORSEPOWER
TRUE AIRSPEED (KNOTS)

FIGURE 4
PROPULSIVE EFFICIENCY
LONG-EZ USA S/N 82-1249 (N1253)

SYM	AVG GROSS WEIGHT (POUNDS)	AVG LONGITUDINAL CG LOCATION (FS)	AVG PRESSURE ALTITUDE (FEET)	CONFIGURATION
□	1229	99.1 (FWD)	3760	CRUISE
○	1270	97.8 (FWD)	7400	CRUISE
△	1310	97.4 (FWD)	12140	CRUISE



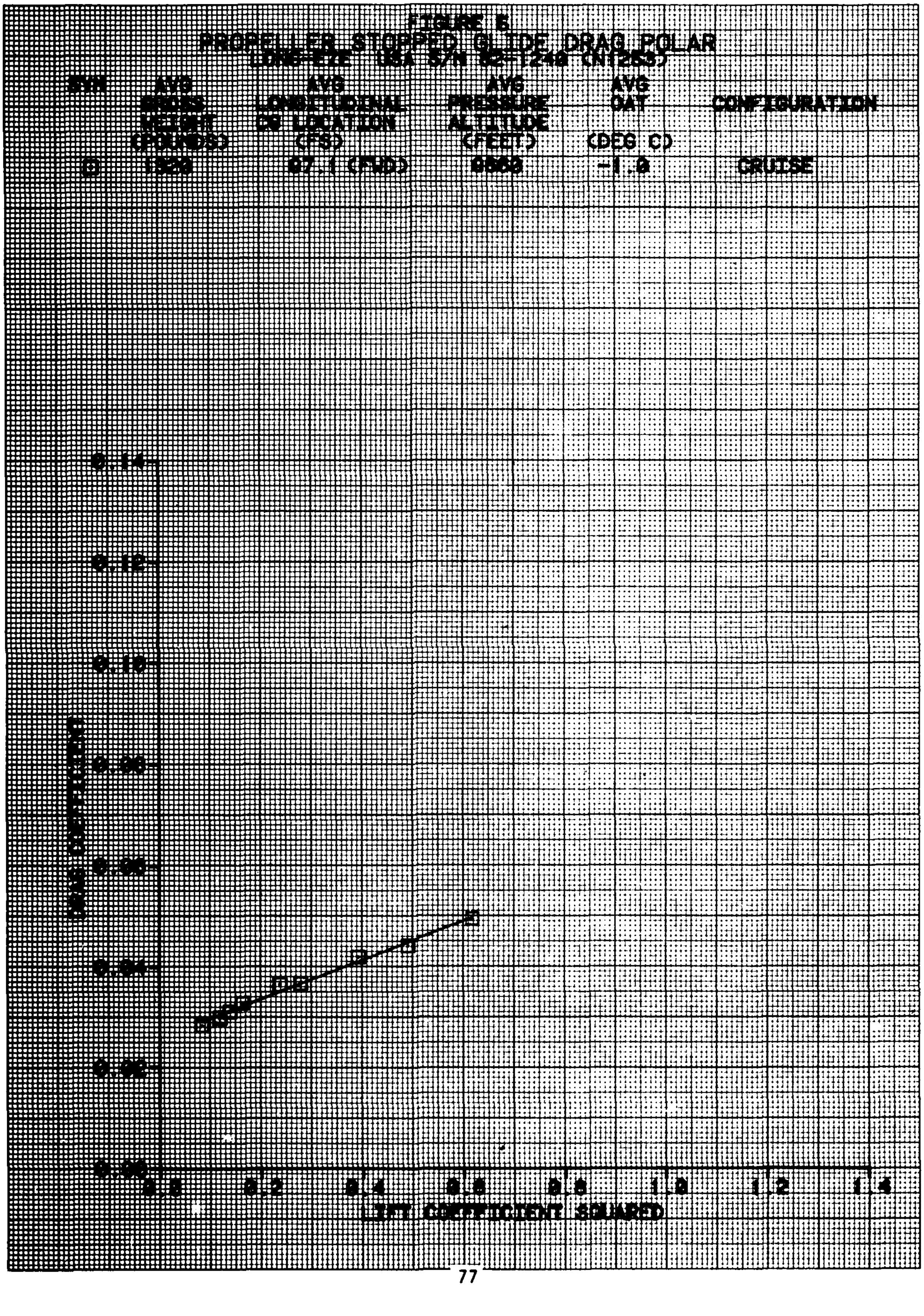


FIGURE 5
PROPELLER STOPPED GLIDE DRAG POLAR
SYM
AVG GROSS WEIGHT (POUNDS)
AVG LONGITUDINAL CG LOCATION (FS)
AVG PRESSURE ALTITUDE (FEET)
AVG OAT (DEG C)
CONFIGURATION
CRUISE
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
DRAG COEFFICIENT
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
LIFT COEFFICIENT SQUARED

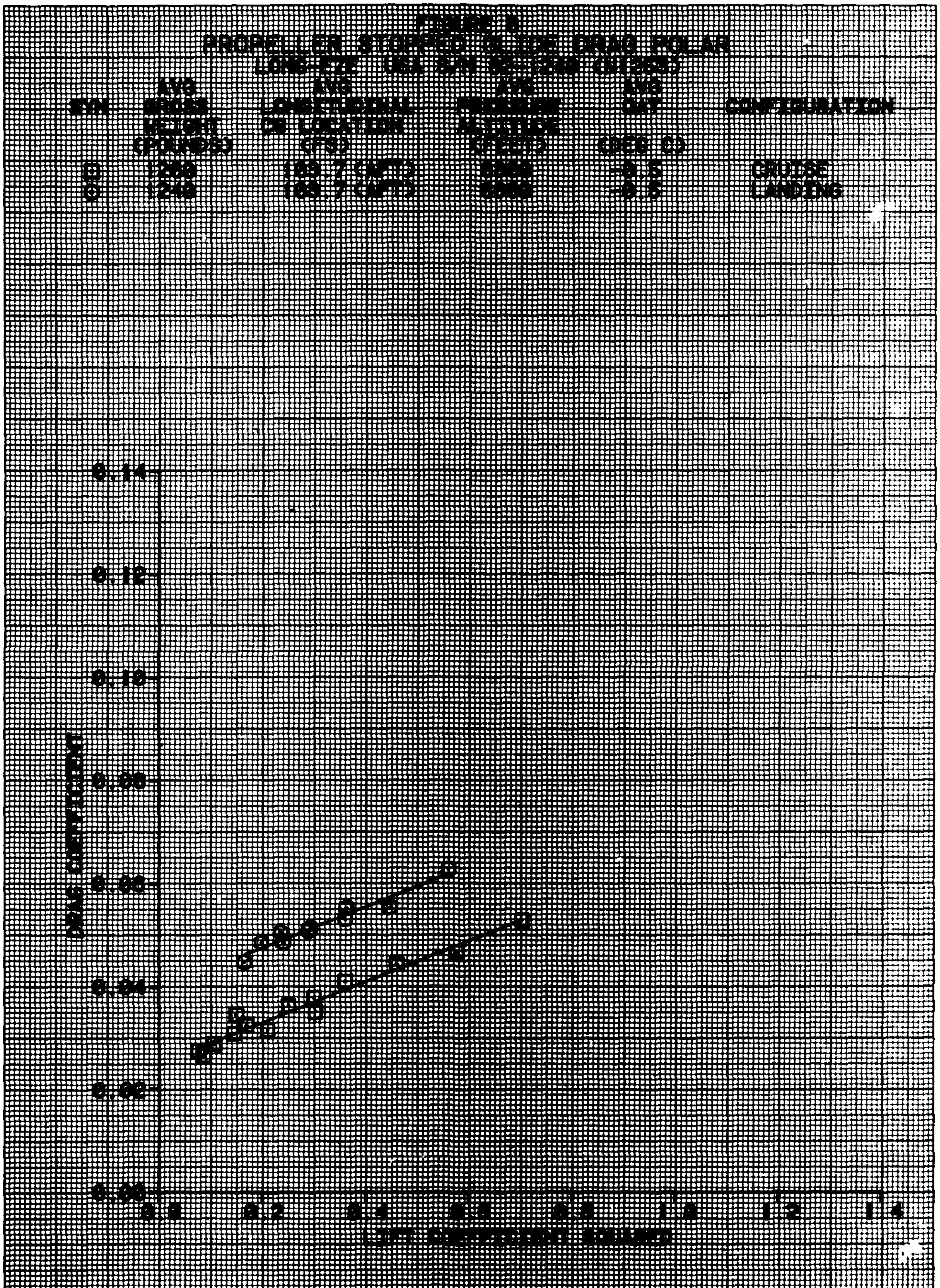

PROPELLER STOPPED GLIDE DRAG POLAR
AVG
CONFIGURATION
CRUISE
LANDING
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
DRAG COEFFICIENT
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
LIFT COEFFICIENT SQUARED

FIGURE 7
STALL PERFORMANCE
LONG-EZ USA S/N 82-1240 (N1263)

GROSS WEIGHT (POUNDS)	LONGITUDINAL CG LOCATION (FS)	DENSITY ALTITUDE (FEET)	OAT (DEG C)	CONFIGURATION
1320	104.8(AFT)	7520	-0.5	TAKE OFF

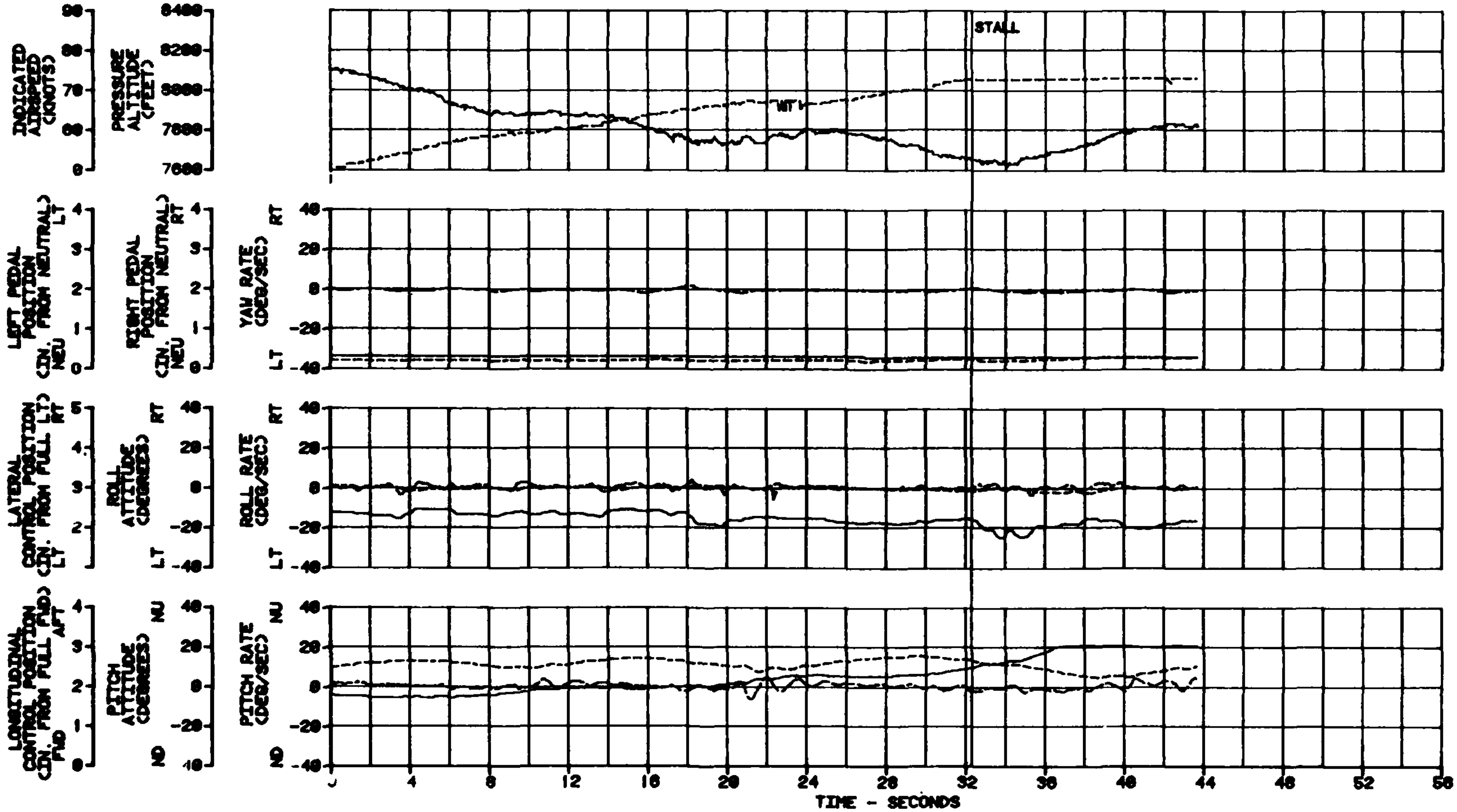


FIGURE 8
STALL PERFORMANCE
LONG-EZ USA S/N 82-1240 (N1253)

GROSS WEIGHT (POUNDS)	LONGITUDINAL CG LOCATION (FS)	DENSITY ALTITUDE (FEET)	OAT (DEG C)	CONFIGURATION
1310	104.8(AFT)	8320	-3.0	CLIMB

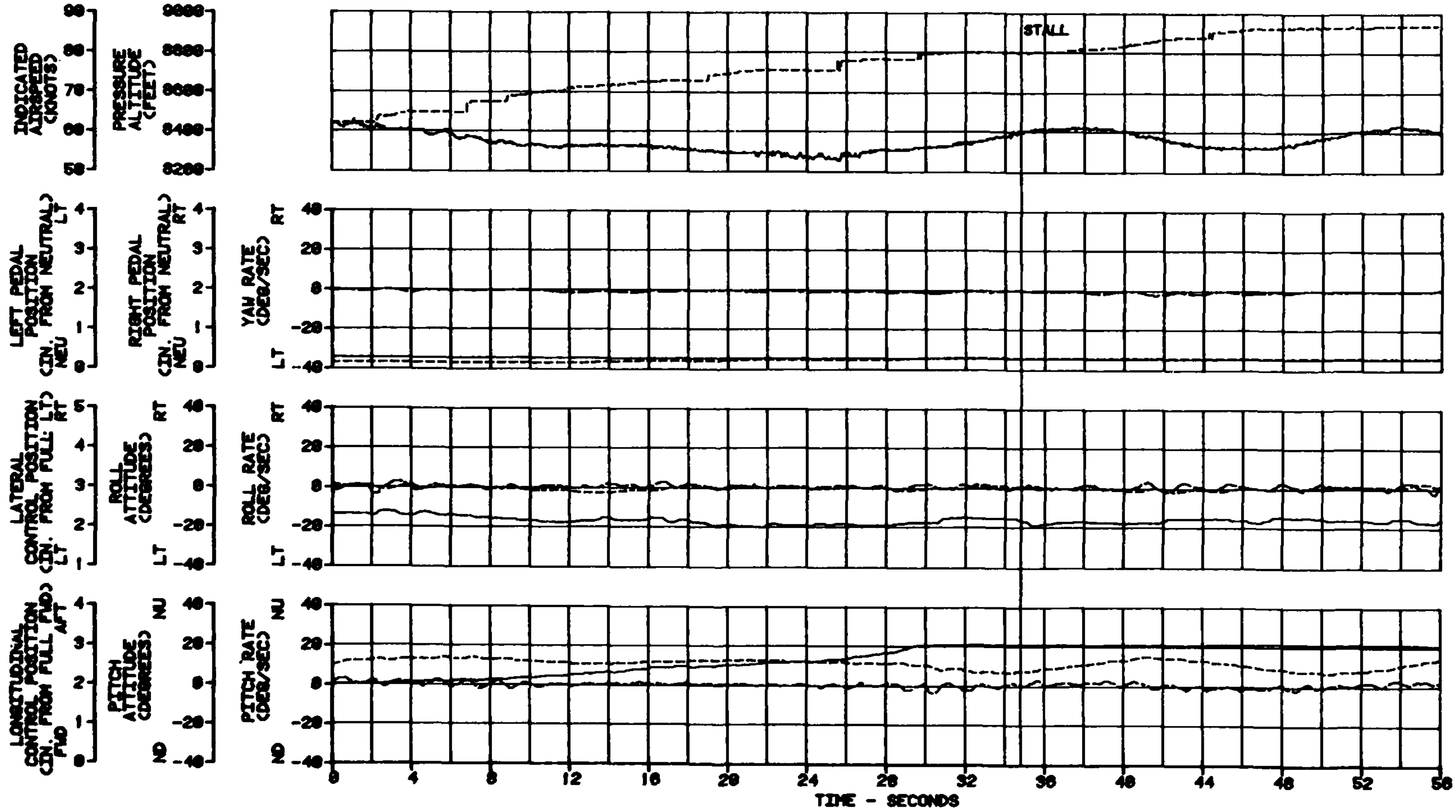


FIGURE 9

STALL PERFORMANCE

LONG-EZ USA S/N 82-1240 (N1253)

GROSS WEIGHT (POUNDS)	LONGITUDINAL CG LOCATION (FS)	DENSITY ALTITUDE (FEET)	OAT (DEG C)	CONFIGURATION
1310	104.8(AFT)	9840	-2.5	CRUISE

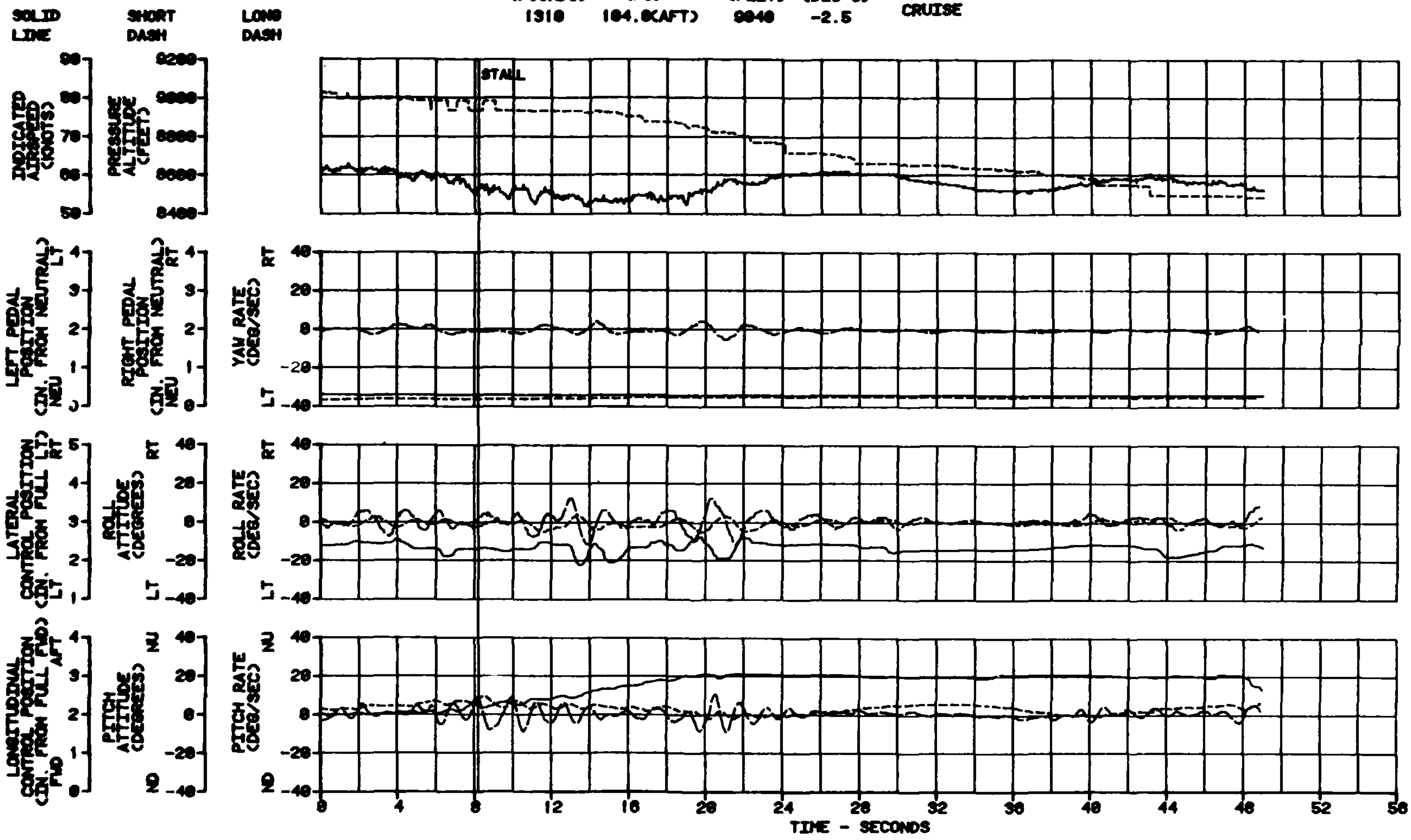


FIGURE 10
STALL PERFORMANCE
LONG-EZ USA S/N 82-1240 (N1253)

GROSS WEIGHT (POUNDS)	LONGITUDINAL CG LOCATION (FS)	DENSITY ALTITUDE (FEET)	OAT (DEG C)	CONFIGURATION
1320	104.8(AFT)	8340	-1.5	APPROACH

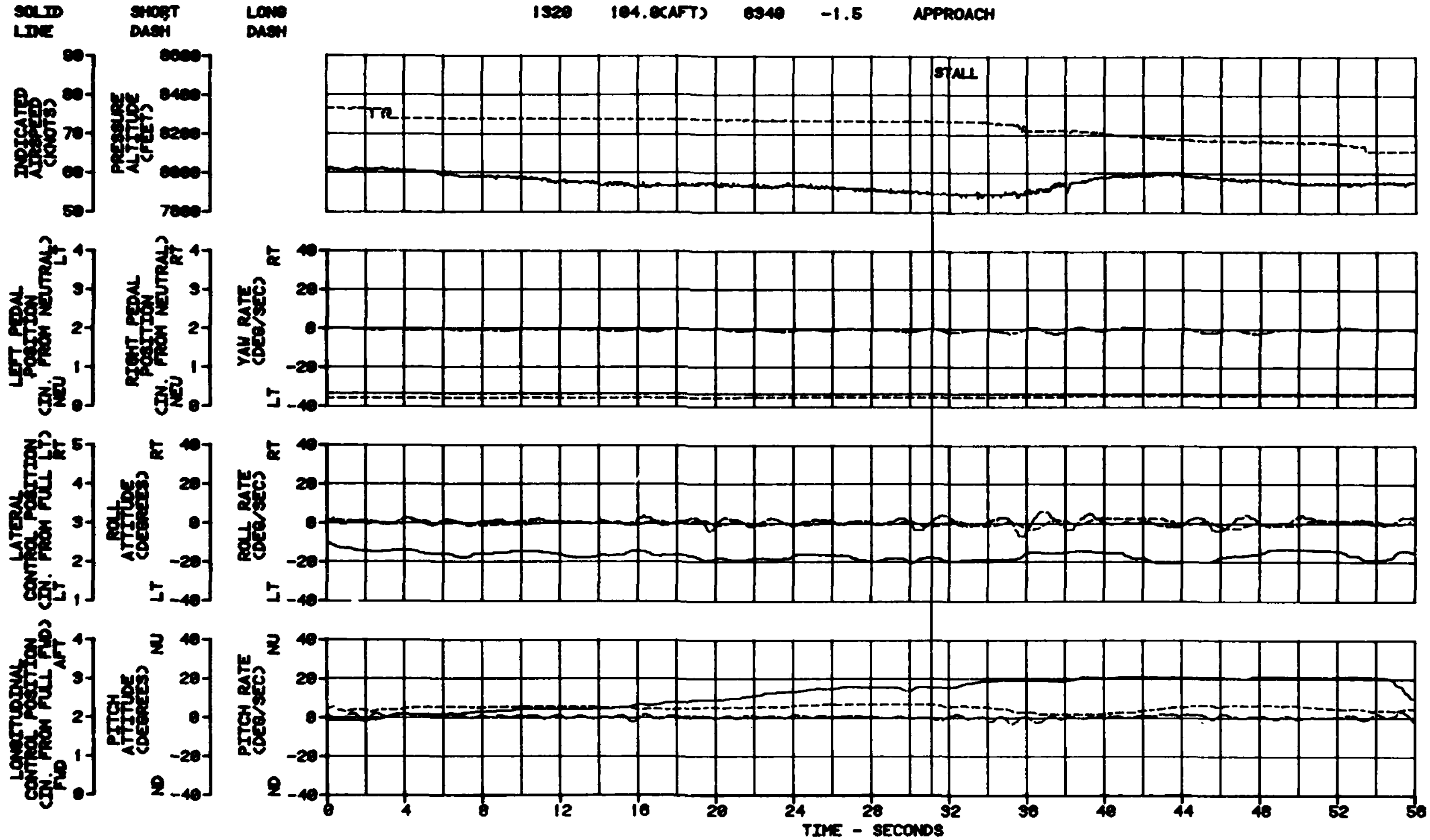


FIGURE 11
STALL PERFORMANCE
LONG-EZ USA S/N 82-1240 (N1253)

GROSS WEIGHT (POUNDS)	LONGITUDINAL CG LOCATION (FS)	DENSITY ALTITUDE (FEET)	OAT (DEG C)	CONFIGURATION
1320	104.0(AFT)	7840	-1.5	LANDING

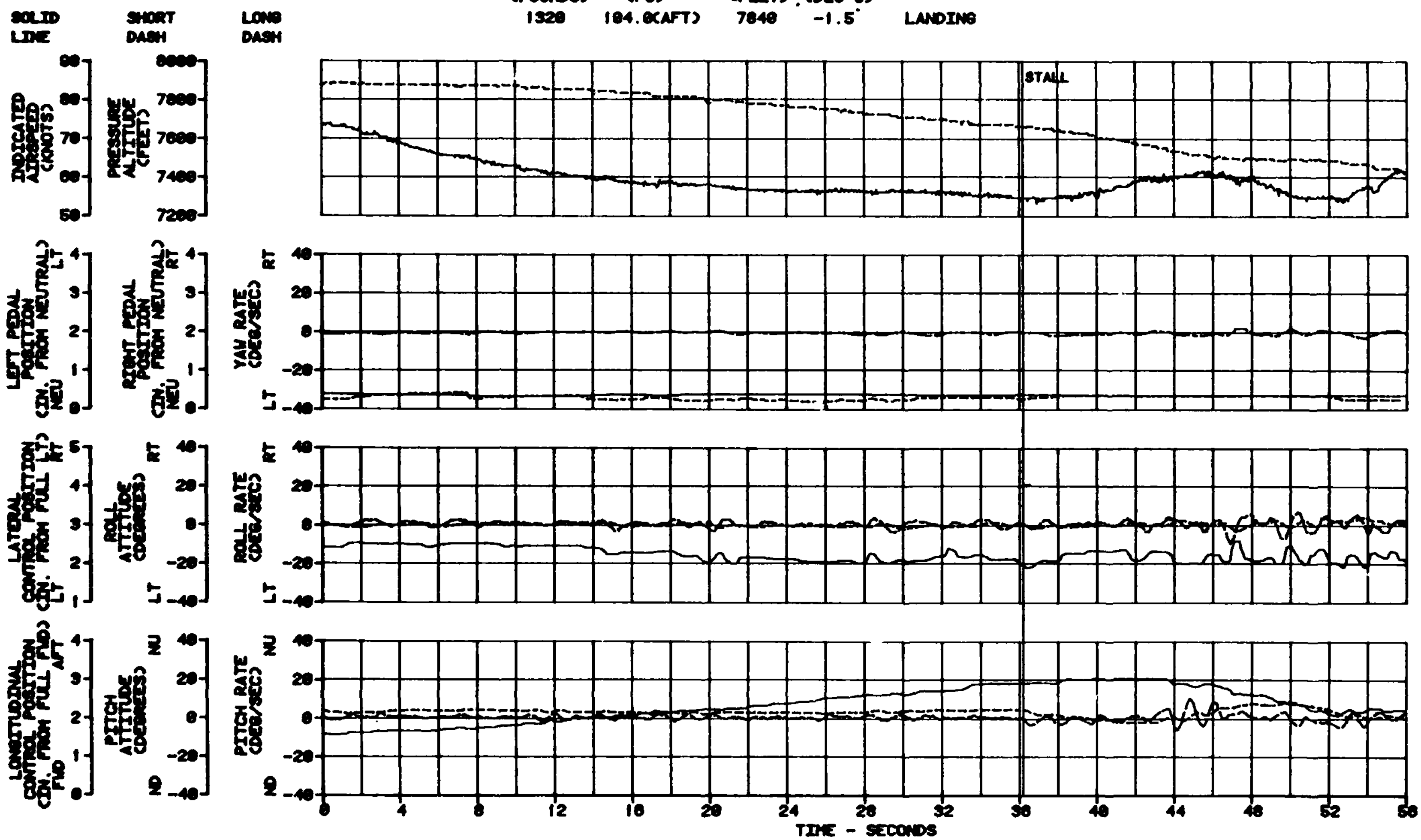


FIGURE 12

STALL PERFORMANCE

LONG-EZ USA S/N 82-1240 (N1253)

GROSS WEIGHT (POUNDS)	LONGITUDINAL CG LOCATION (FS)	DENSITY ALTITUDE (FEET)	OAT (DEG C)	CONFIGURATION
1300	103.9(AFT)	6240	2.0	TAKE OFF, ACCELERATED

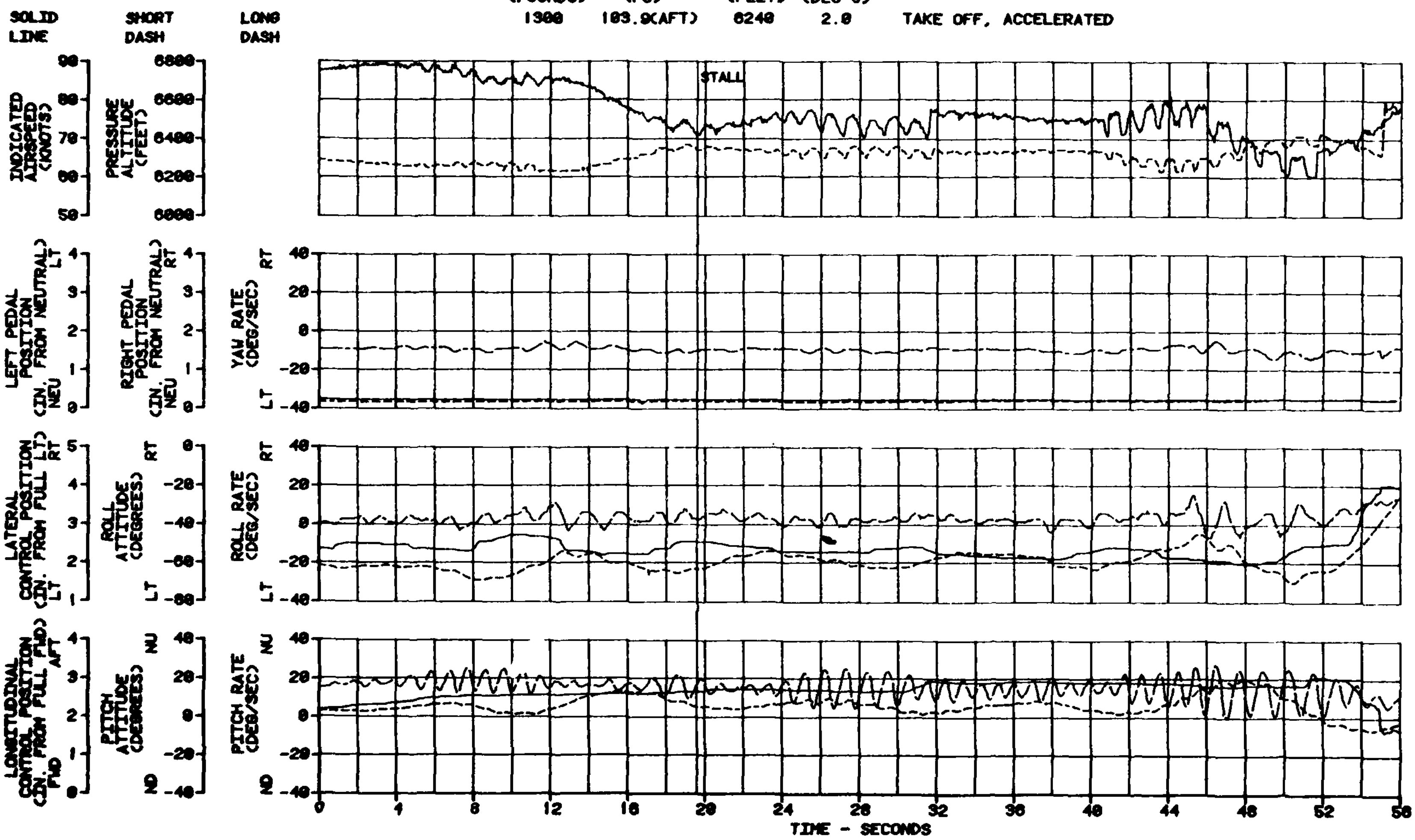


FIGURE 13
STALL PERFORMANCE
LONG-EZ USA S/N 82-1240 (N1253)

GROSS WEIGHT (POUNDS)	LONGITUDINAL CG LOCATION (FS)	DENSITY ALTITUDE (FEET)	OAT (DEG C)	CONFIGURATION
1210	98.2(FWD)	8840	8.0	CRUISE

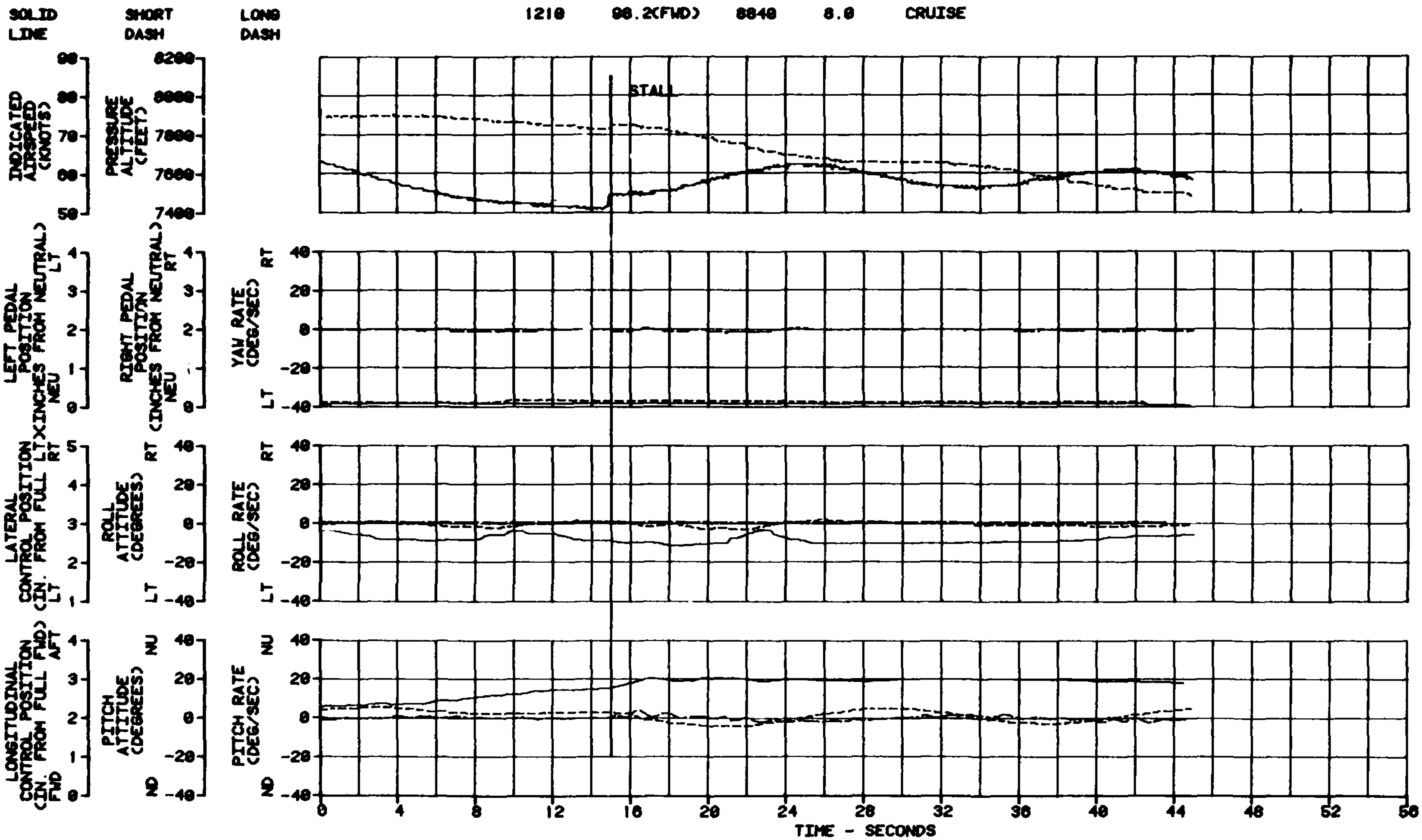
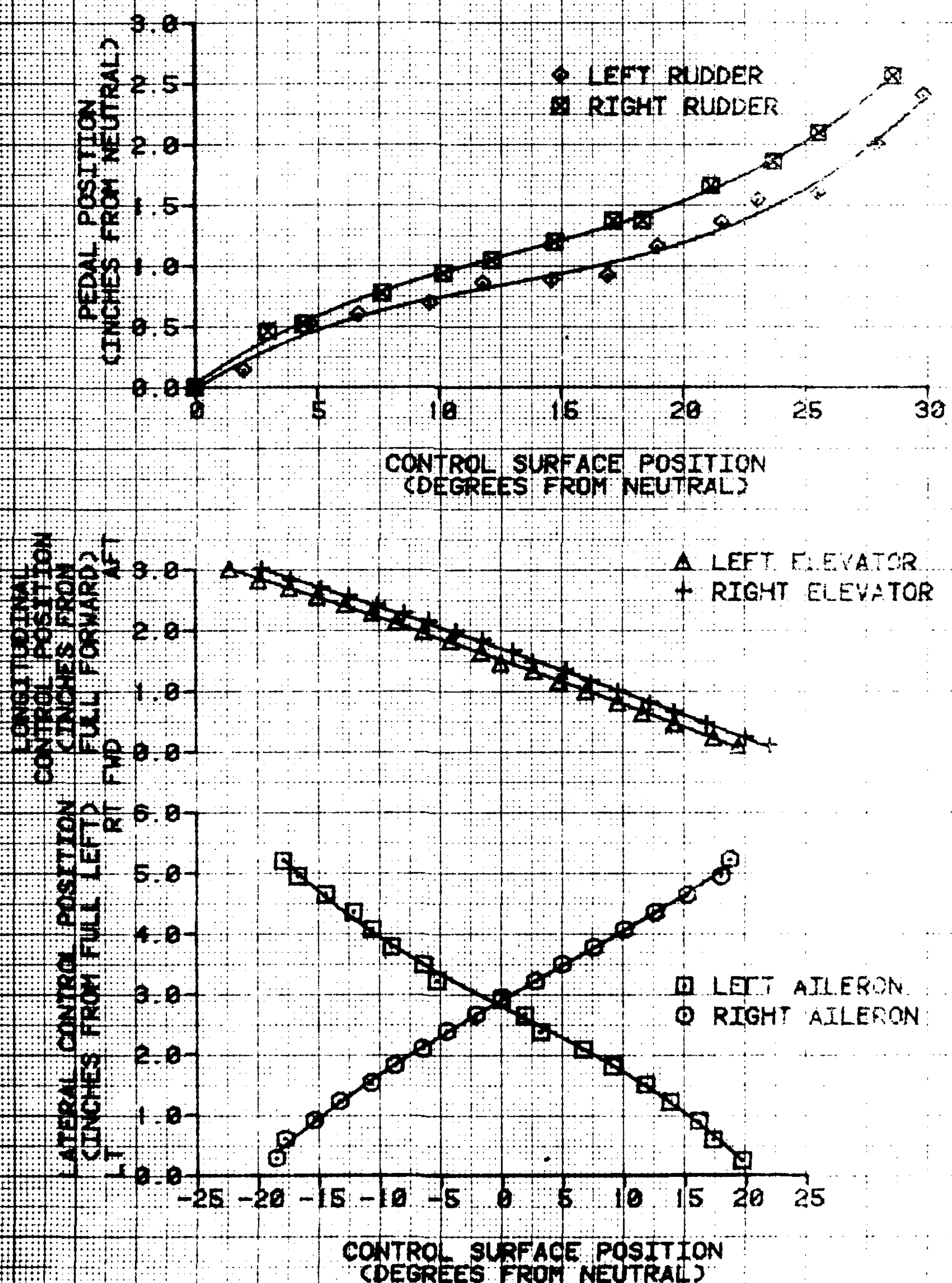


FIGURE 14
COCKPIT CONTROL/CONTROL SURFACE RELATIONSHIP
LONG-EZ S/N 82-1240 (N1253)

NOTE: STATIC CONDITION (NO AERODYNAMIC LOADS)



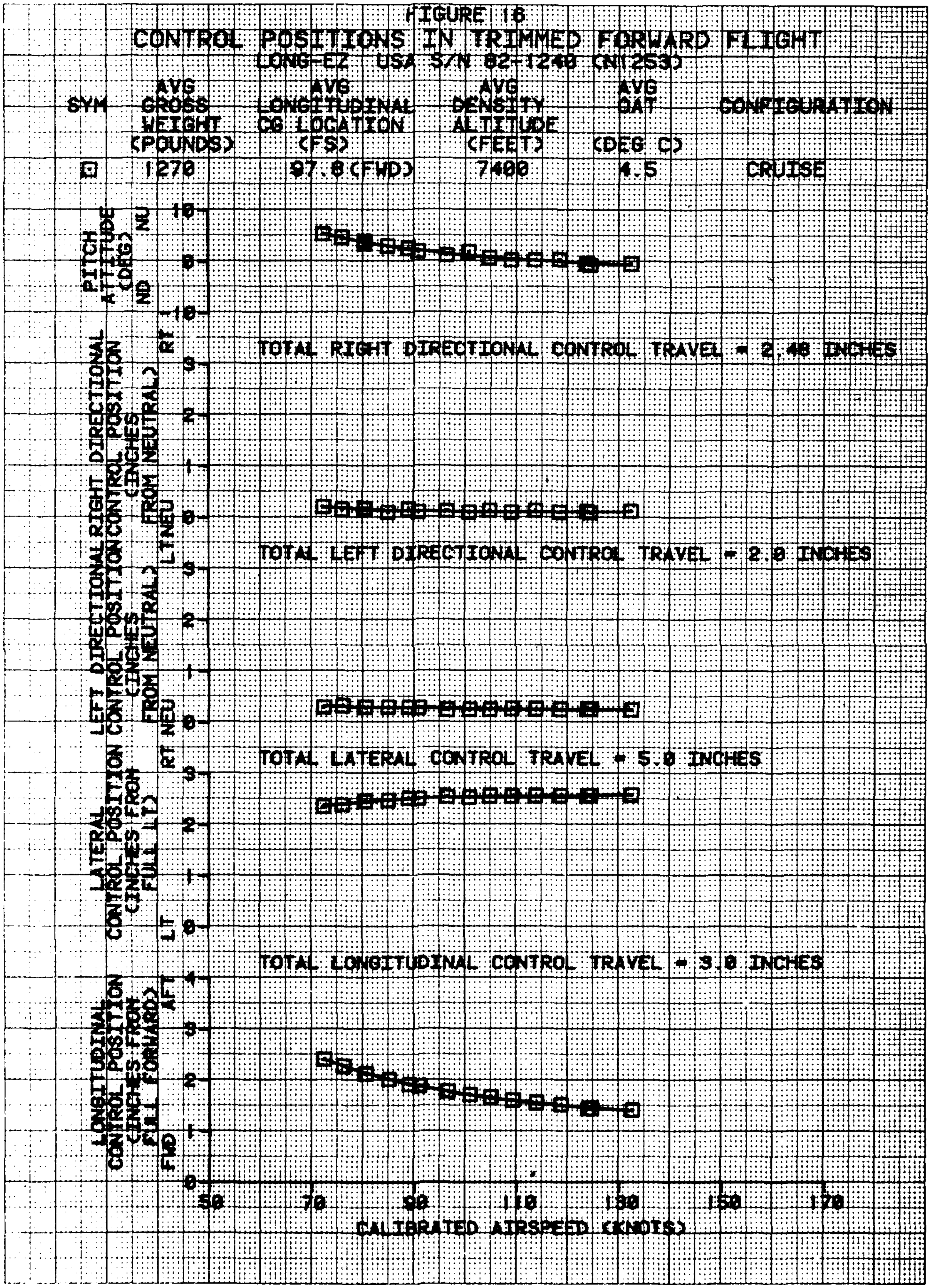
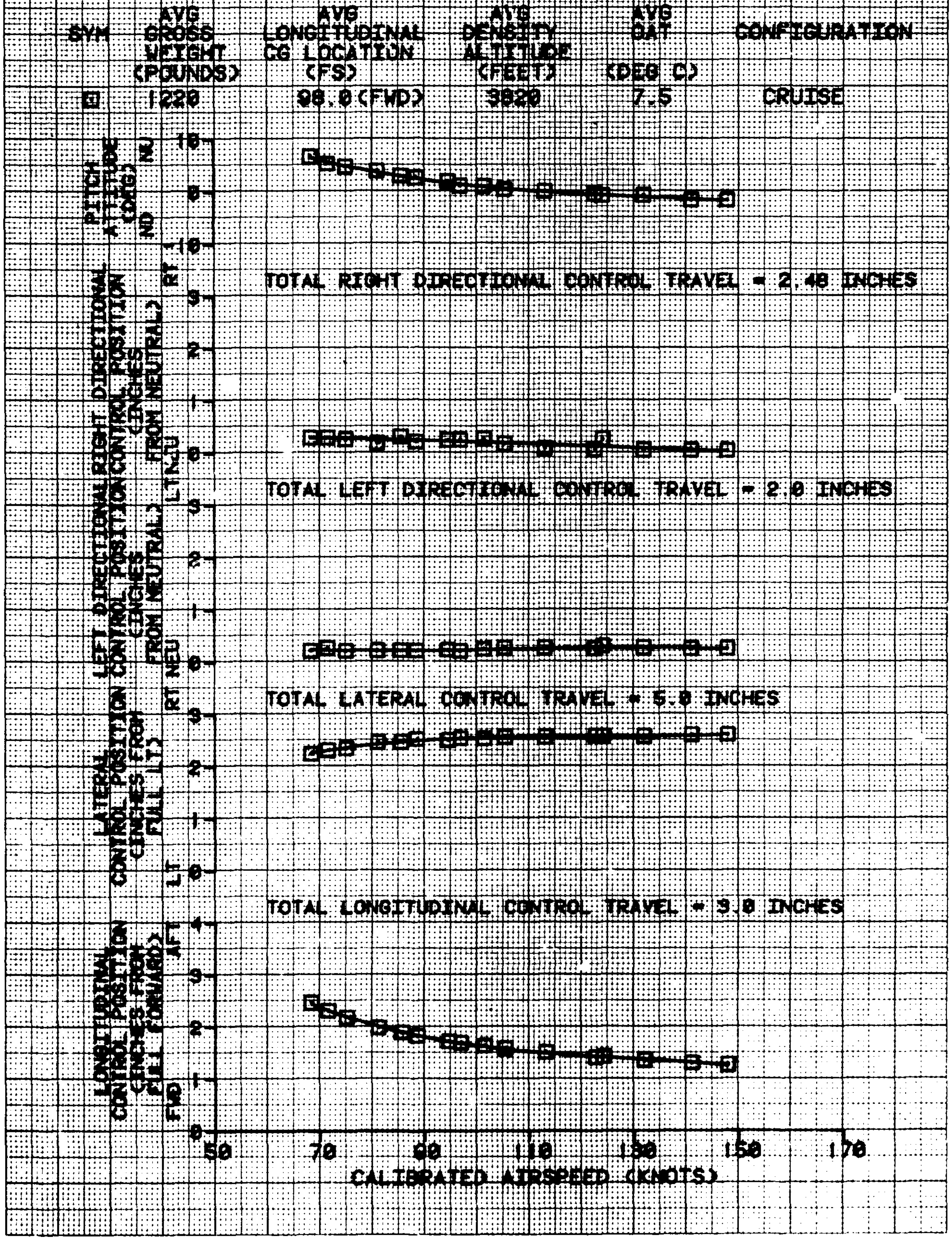


FIGURE 16
CONTROL POSITIONS IN TRIMMED FORWARD FLIGHT
LONG-EZ USA S/N 82-1240 (N1253)
SYM
AVG GROSS WEIGHT (POUNDS)
AVG LONGITUDINAL CG LOCATION (FS)
AVG DENSITY ALTITUDE (FEET)
AVG OAT (DEG C)
CONFIGURATION
1270
97.8 (FWD)
7400
4.5
CRUISE
PITCH ATTITUDE (DEG)
NU
ND
RIGHT DIRECTIONAL CONTROL POSITION (INCHES FROM NEUTRAL)
RT
NEU
TOTAL RIGHT DIRECTIONAL CONTROL TRAVEL = 2.40 INCHES
LEFT DIRECTIONAL CONTROL POSITION (INCHES FROM NEUTRAL)
LT
NEU
TOTAL LEFT DIRECTIONAL CONTROL TRAVEL = 2.0 INCHES
LATERAL CONTROL POSITION (INCHES FROM FULL LT)
RT
LT
TOTAL LATERAL CONTROL TRAVEL = 5.0 INCHES
LONGITUDINAL CONTROL POSITION (INCHES FROM FULL FORWARD)
AFT
FWD
TOTAL LONGITUDINAL CONTROL TRAVEL = 3.0 INCHES
CALIBRATED AIRSPEED (KNOTS)

FIGURE 15
CONTROL POSITIONS IN TRIMMED FORWARD FLIGHT
LONG-EZ USA S/N 82-1240 (N1253)



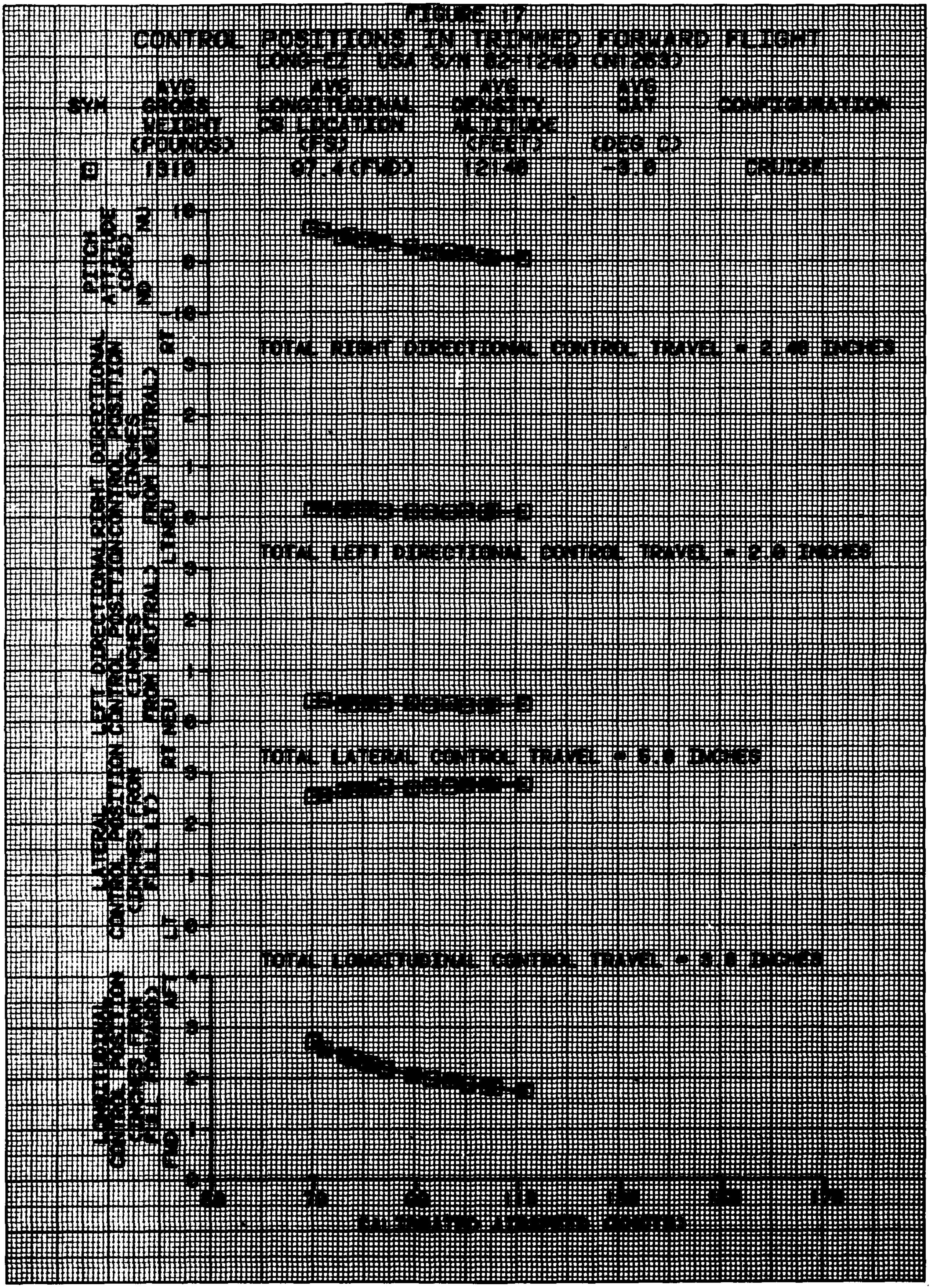
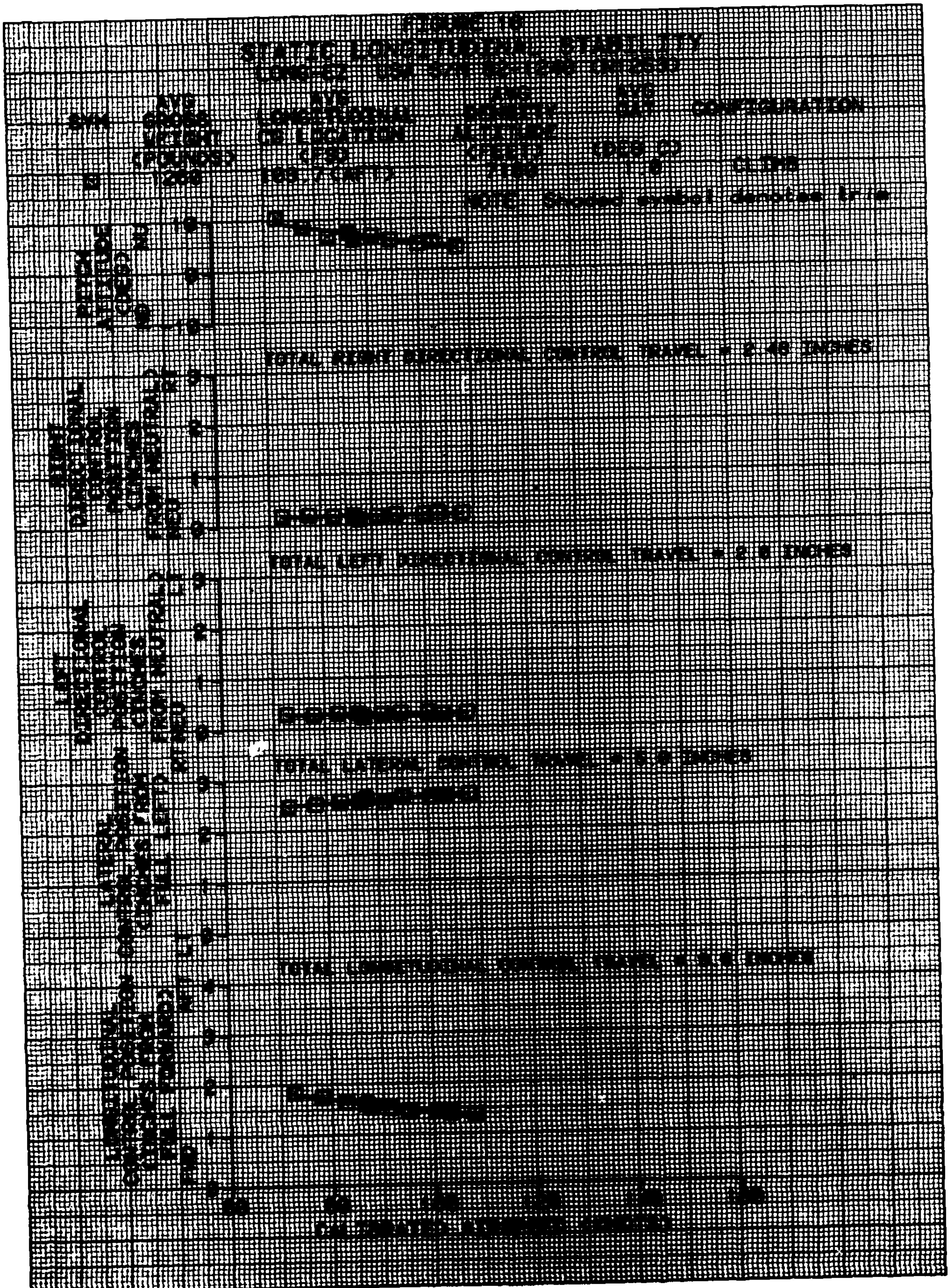
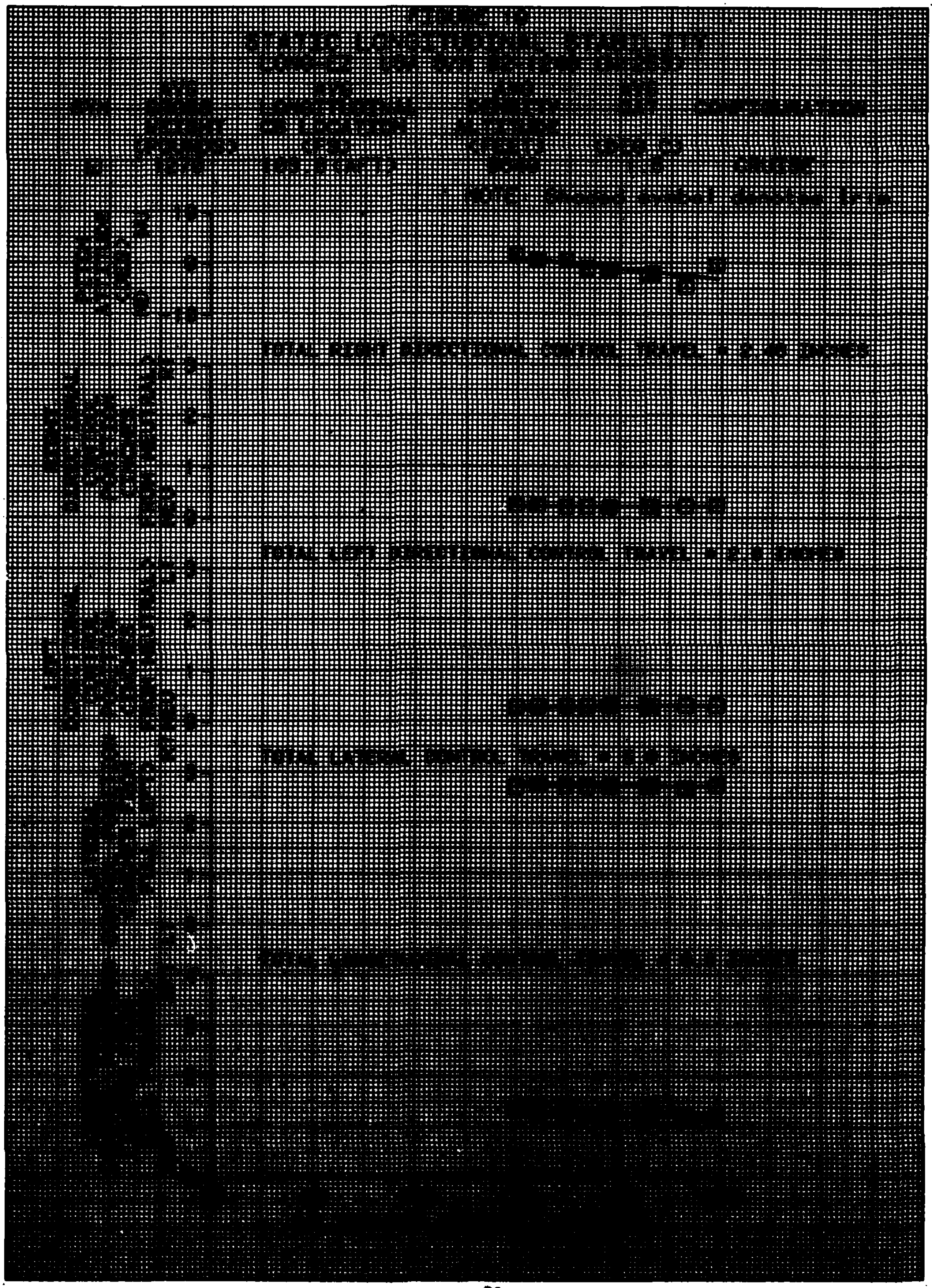
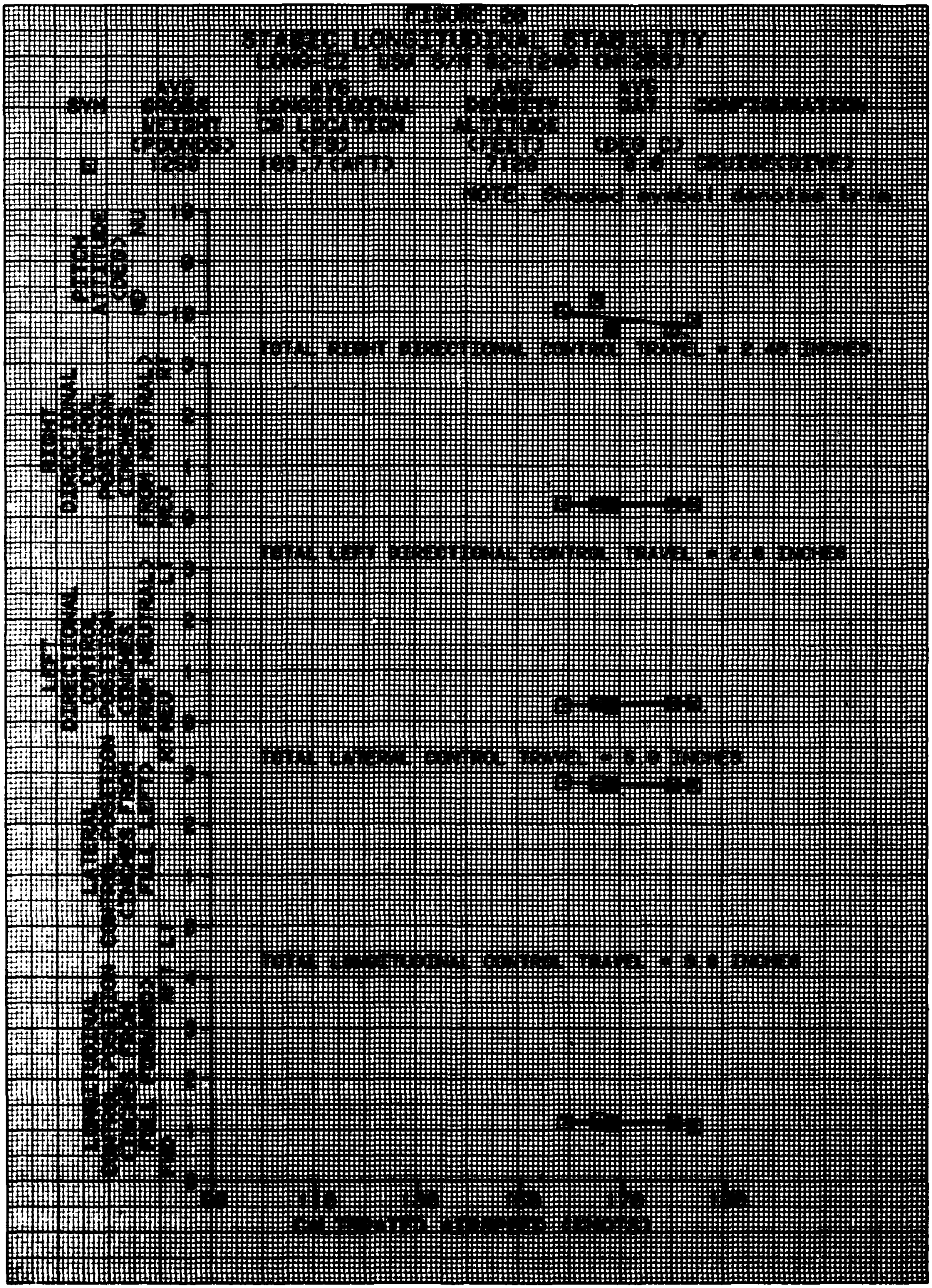


FIGURE 17
CONTROL POSITIONS IN TRIMMED FORWARD FLIGHT
LONG-EZ USA S/N 82-1248 (N1263)
SYM
AVG GROSS WEIGHT (POUNDS)
AVG LONGITUDINAL CG LOCATION (FS)
AVG DENSITY ALTITUDE (FEET)
AVG OAT (DEG C)
CONFIGURATION
1310
97.4(FWD)
12140
-3.0
CRUISE
PITCH ATTITUDE (DEG)
NU
ND
LEFT DIRECTIONAL CONTROL POSITION (INCHES FROM NEUTRAL)
RIGHT DIRECTIONAL CONTROL POSITION (INCHES FROM NEUTRAL)
LATERAL CONTROL POSITION (INCHES FROM FULL LT)
LONGITUDINAL CONTROL POSITION (INCHES FROM FULL FORWARD)
TOTAL RIGHT DIRECTIONAL CONTROL TRAVEL = 2.40 INCHES
TOTAL LEFT DIRECTIONAL CONTROL TRAVEL = 2.6 INCHES
TOTAL LATERAL CONTROL TRAVEL = 5.6 INCHES
TOTAL LONGITUDINAL CONTROL TRAVEL = 3.6 INCHES
CALIBRATED AIRSPEED (KNOTS)


STATIC LONGITUDINAL STABILITY




STATIC LONGITUDINAL STABILITY
TOTAL LATERAL CONTROL TRAVEL
TOTAL LONGITUDINAL CONTROL TRAVEL
CALIBRATED AIRSPEED (KNOTS)

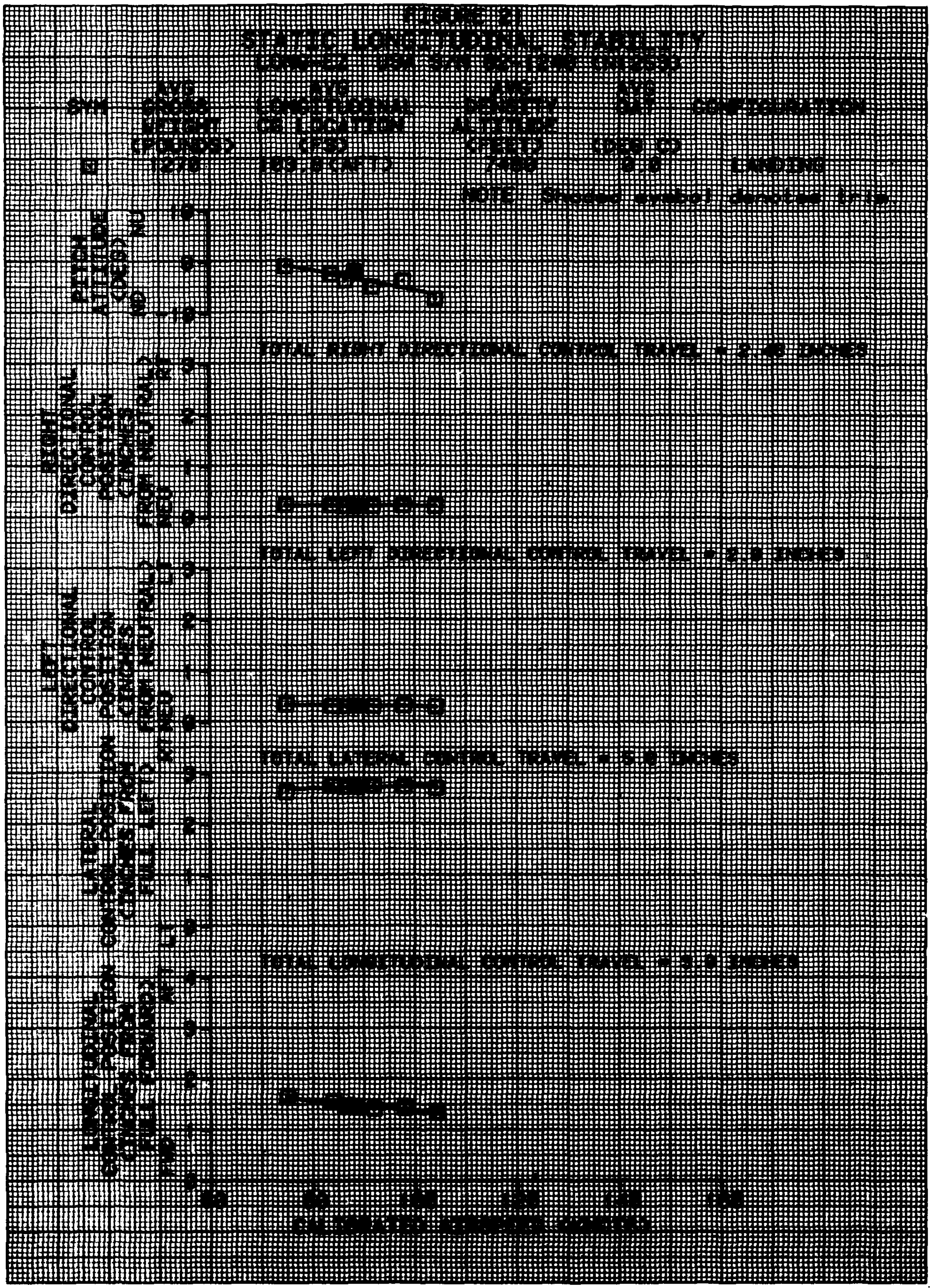


FIGURE 21
STATIC LONGITUDINAL STABILITY
AVG GROSS WEIGHT (POUNDS)
AVG LONGITUDINAL CG LOCATION (FS)
AVG DENSITY ALTITUDE (FEET)
AVG OAT (DEG C)
CONFIGURATION
LANDING
TOTAL RIGHT DIRECTIONAL CONTROL TRAVEL
TOTAL LEFT DIRECTIONAL CONTROL TRAVEL
TOTAL LATERAL CONTROL TRAVEL
TOTAL LONGITUDINAL CONTROL TRAVEL
CALIBRATED AIRSPEED (KNOTS)

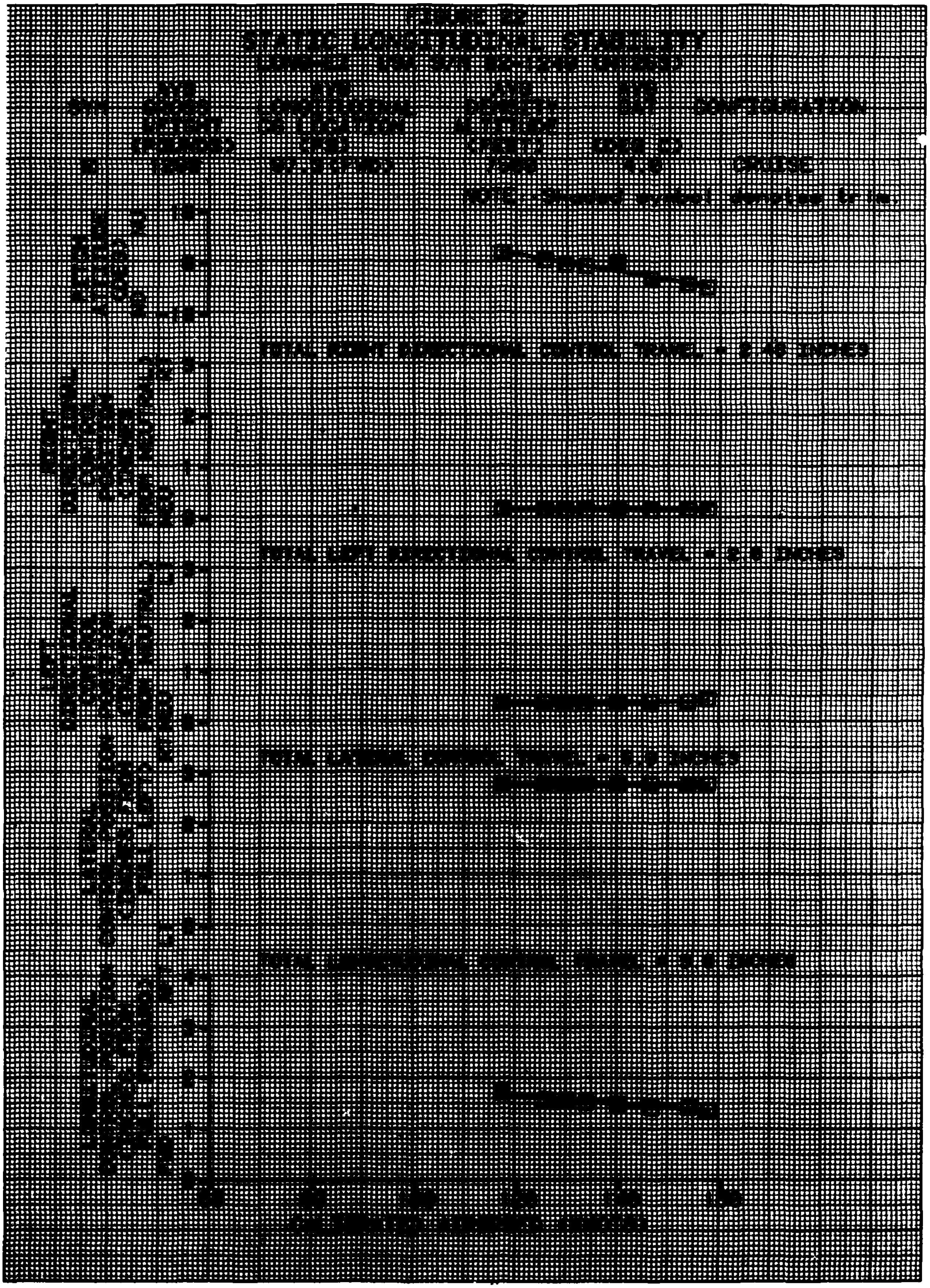


FIGURE 22
STATIC LONGITUDINAL STABILITY
CONFIGURATION
CRUISE

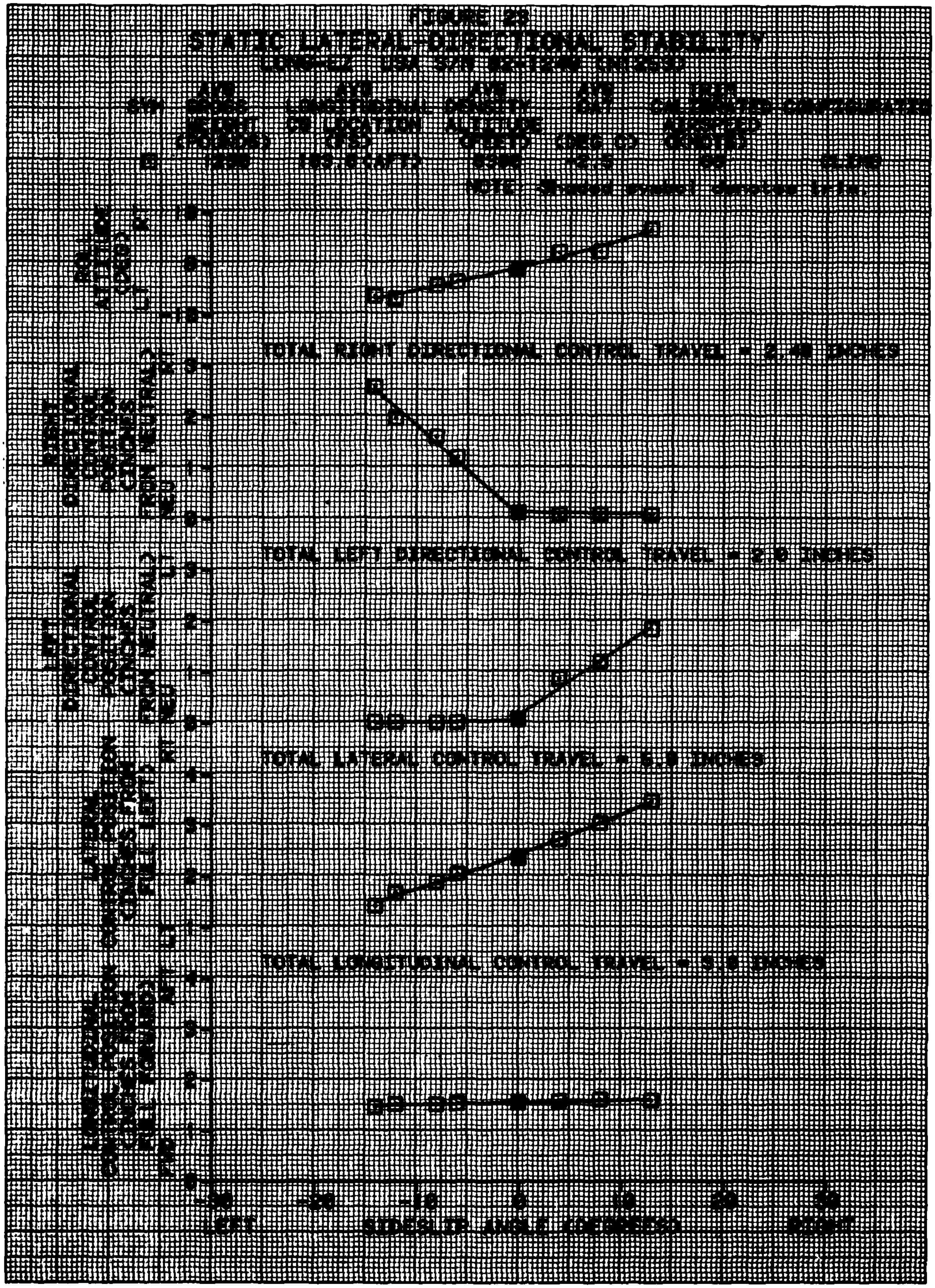
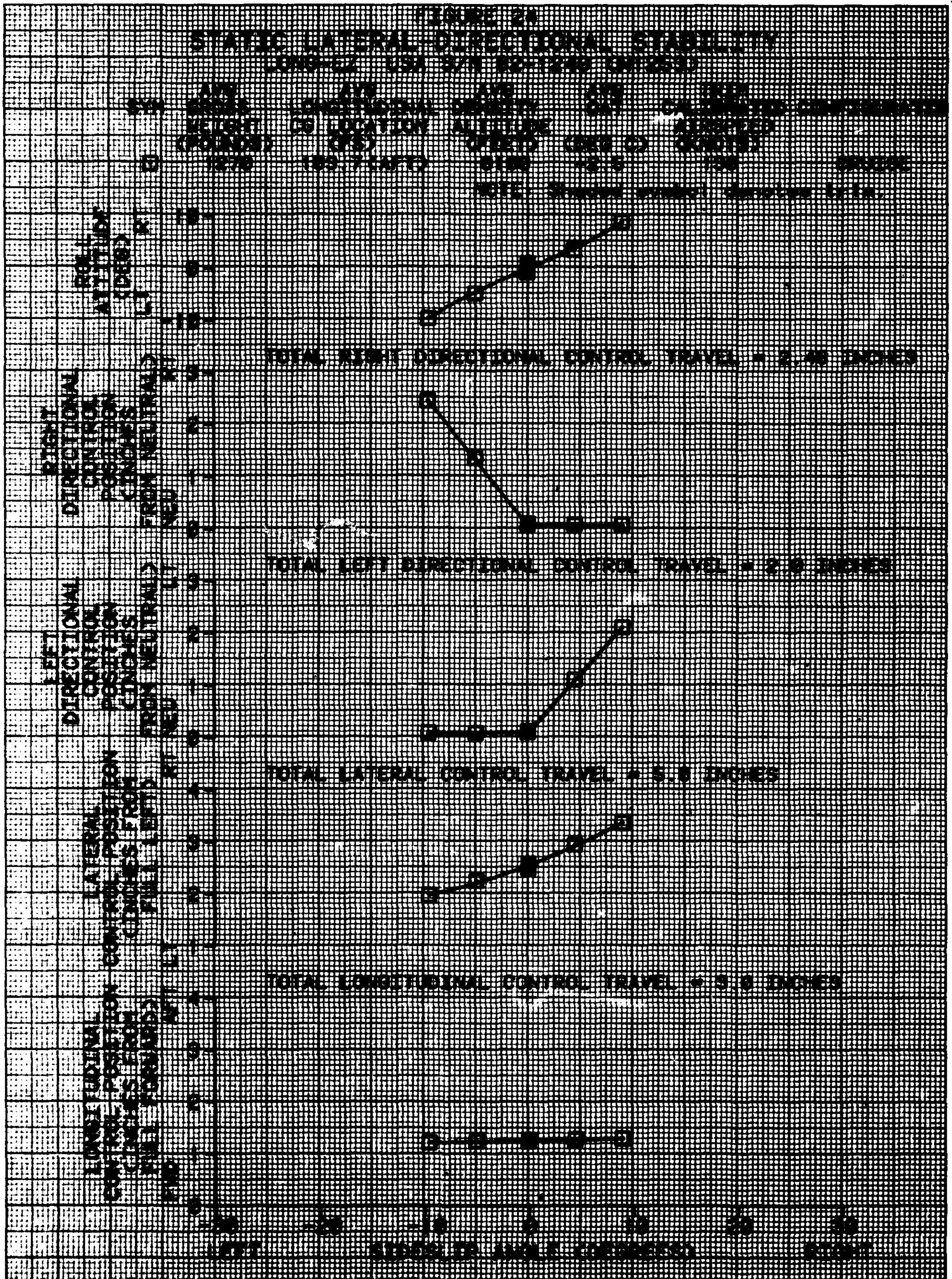
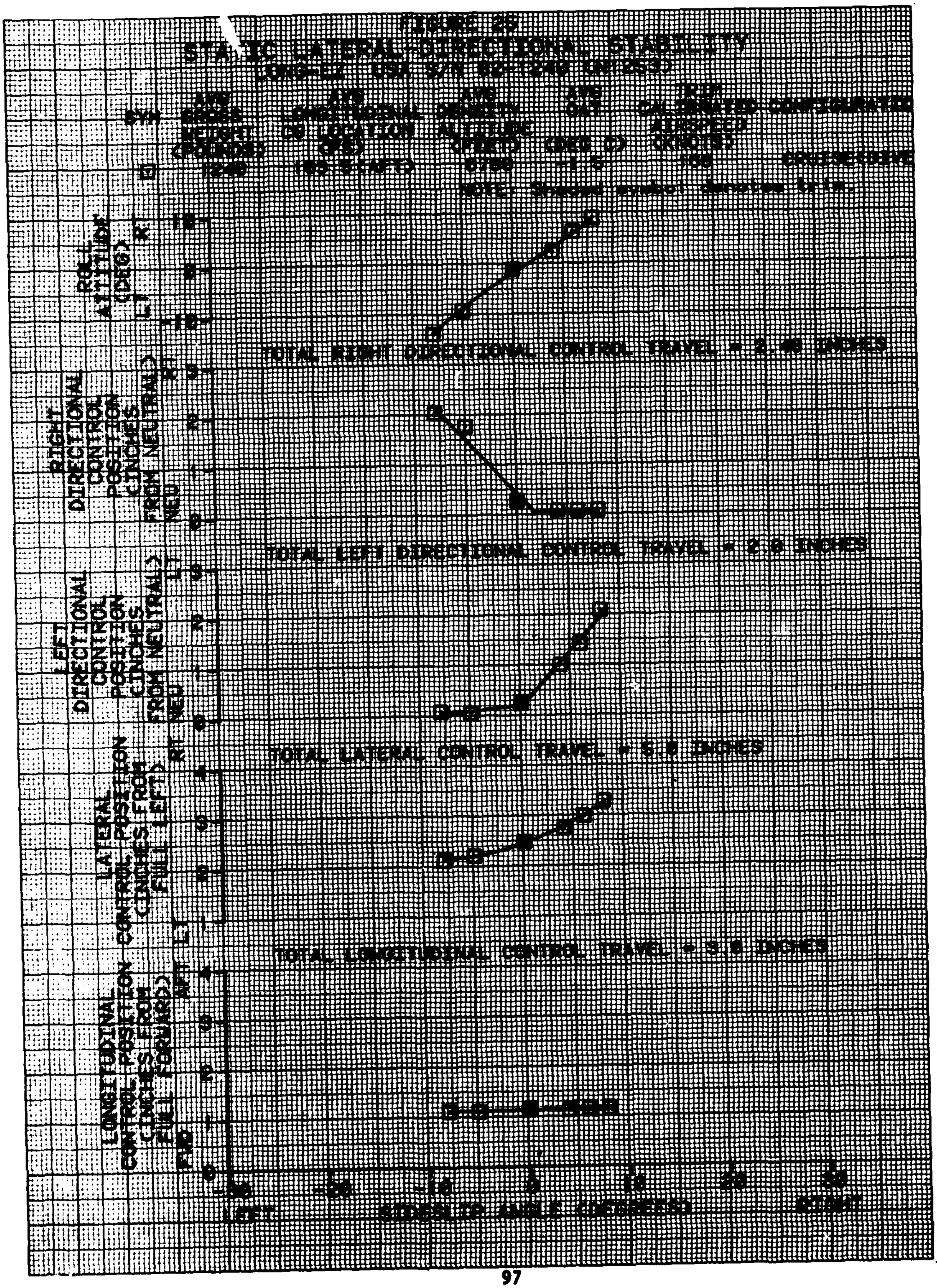


FIGURE 23
STATIC LATERAL-DIRECTIONAL STABILITY
TOTAL RIGHT DIRECTIONAL CONTROL TRAVEL
TOTAL LEFT DIRECTIONAL CONTROL TRAVEL
TOTAL LATERAL CONTROL TRAVEL
TOTAL LONGITUDINAL CONTROL TRAVEL
-30
-20
-10
0
10
20
30
LEFT
RIGHT



STATIC LATERAL-DIRECTIONAL STABILITY
TOTAL RIGHT DIRECTIONAL CONTROL TRAVEL
TOTAL LEFT DIRECTIONAL CONTROL TRAVEL
TOTAL LATERAL CONTROL TRAVEL
TOTAL LONGITUDINAL CONTROL TRAVEL
RIGHT DIRECTIONAL CONTROL POSITION (INCHES FROM NEUTRAL)
LEFT DIRECTIONAL CONTROL POSITION (INCHES FROM NEUTRAL)
LATERAL CONTROL POSITION
LONGITUDINAL CONTROL POSITION
LEFT
SIDESLIP ANGLE (DEGREES)
RIGHT


STATIC LATERAL-DIRECTIONAL STABILITY
TOTAL RIGHT DIRECTIONAL CONTROL TRAVEL
TOTAL LEFT DIRECTIONAL CONTROL TRAVEL
TOTAL LATERAL CONTROL TRAVEL
TOTAL LONGITUDINAL CONTROL TRAVEL
ROLL ATTITUDE (DEG)
RIGHT DIRECTIONAL CONTROL POSITION (INCHES FROM NEUTRAL)
LEFT DIRECTIONAL CONTROL POSITION (INCHES FROM NEUTRAL)
LATERAL CONTROL POSITION (INCHES FROM FULL LEFT)
LONGITUDINAL CONTROL POSITION (INCHES FROM FULL FORWARD)
LEFT
SIDESLIP ANGLE (DEGREES)
RIGHT

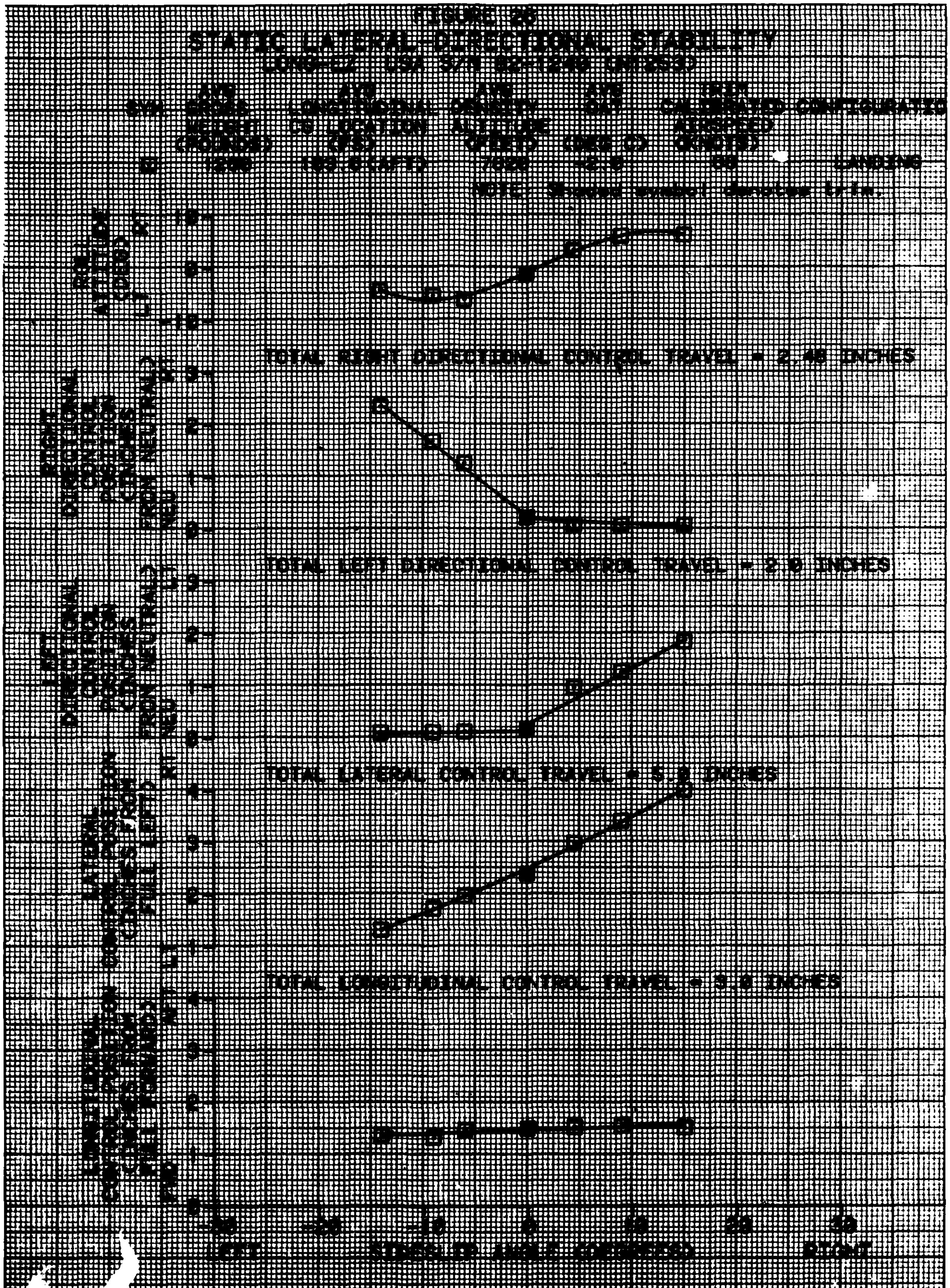


FIGURE 26
STATIC LATERAL-DIRECTIONAL STABILITY
TOTAL RIGHT DIRECTIONAL CONTROL TRAVEL = 2.48 INCHES
TOTAL LEFT DIRECTIONAL CONTROL TRAVEL
TOTAL LATERAL CONTROL TRAVEL
TOTAL LONGITUDINAL CONTROL TRAVEL
-30
-20
-10
0
10
20
30
LEFT
SIDESLIP ANGLE (DEGREES)
RIGHT

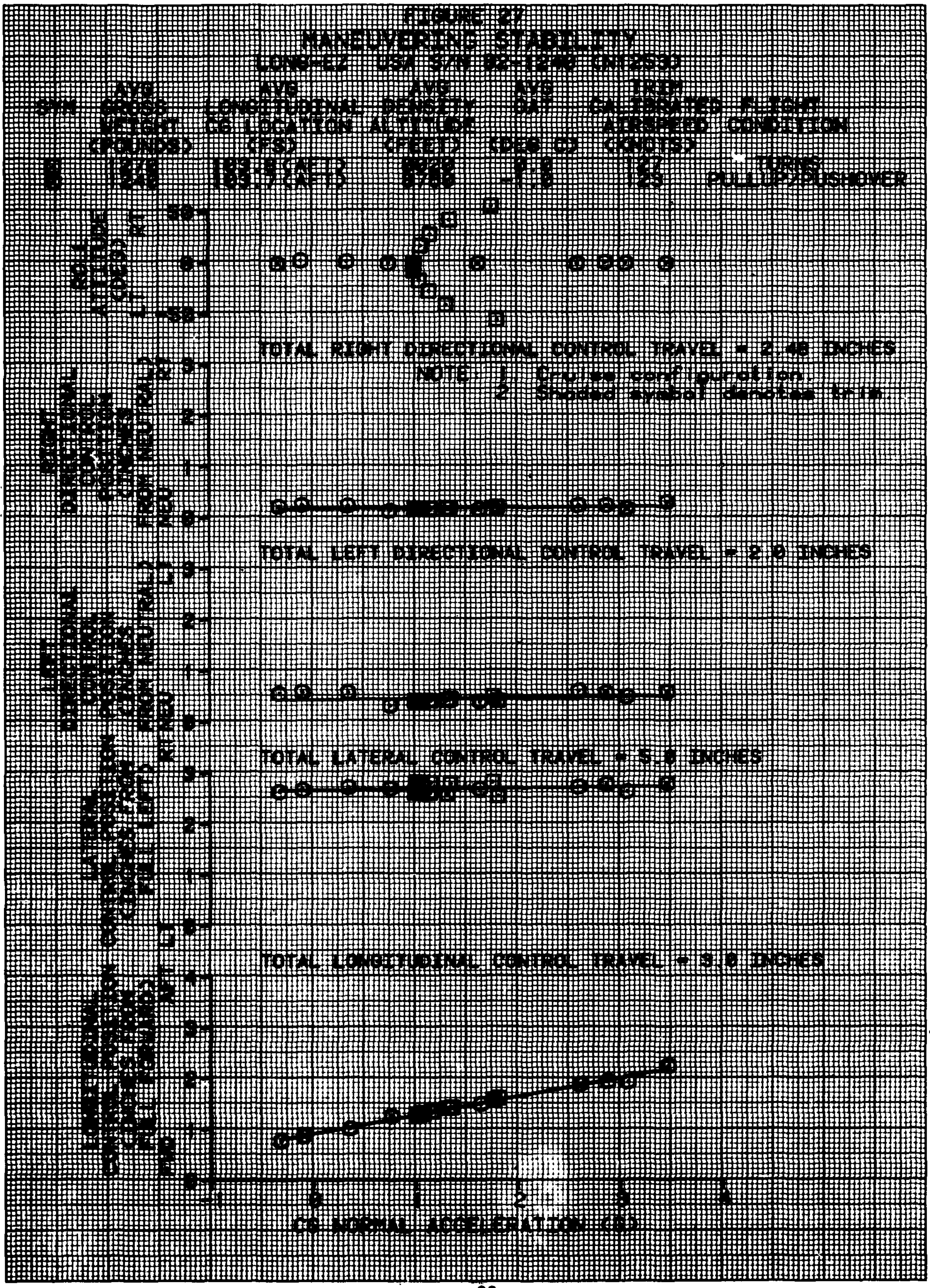


FIGURE 27
MANEUVERING STABILITY

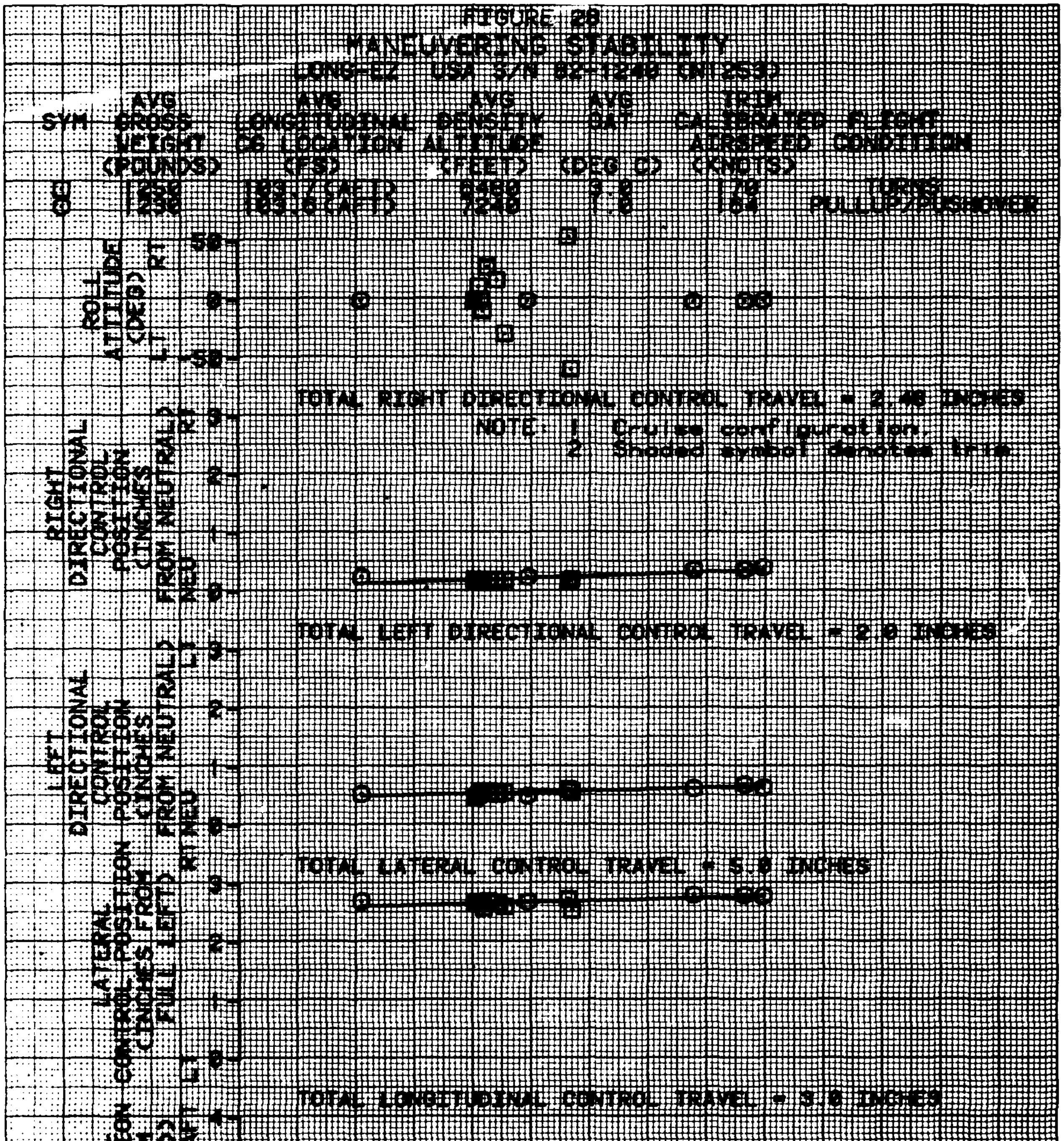


FIGURE 28
MANEUVERING STABILITY
LONG-EZ USA S/N 82-1240 (N1253)
SYM
AVG GROSS WEIGHT (POUNDS)
AVG LONGITUDINAL CG LOCATION (FS)
AVG DENSITY ALTITUDE (FEET)
AVG OAT (DEG C)
TRIM CALIBRATED AIRSPEED (KNOTS)
FLIGHT CONDITION
1250
7240
164
PULLUP/PUSHOVER
ROLL ATTITUDE (DEG) RT LT
50
0
-50
TOTAL RIGHT DIRECTIONAL CONTROL TRAVEL = 2.40 INCHES
NOTE: 1. Cruise configuration.
2. Shaded symbol denotes trim.
RIGHT DIRECTIONAL CONTROL POSITION (INCHES FROM NEUTRAL) RT NEU
TOTAL LEFT DIRECTIONAL CONTROL TRAVEL = 2.0 INCHES
LEFT DIRECTIONAL CONTROL POSITION (INCHES FROM NEUTRAL) LT NEU
TOTAL LATERAL CONTROL TRAVEL = 5.0 INCHES
LATERAL CONTROL POSITION (INCHES FROM FULL LEFT) RT LT
TOTAL LONGITUDINAL CONTROL TRAVEL = 3.8 INCHES
LONGITUDINAL CONTROL POSITION (INCHES FROM FULL FORWARD) AFT FWD
-1
0
1
2
3
4
CG NORMAL ACCELERATION (G)

FIGURE 29
MANEUVERING STABILITY
LONG-EZ USA S/N 82-1240 (N1253)

SYM	AVG GROSS WEIGHT (POUNDS)	AVG LONGITUDINAL CG LOCATION (FS)	AVG DENSITY ALTITUDE (FEET)	AVG OAT (DEG C)	TRIM CALIBRATED AIRSPEED (KNOTS)	FLIGHT CONDITION
□	1240	98.4(FWD)	9400	8.0	127	TURNS

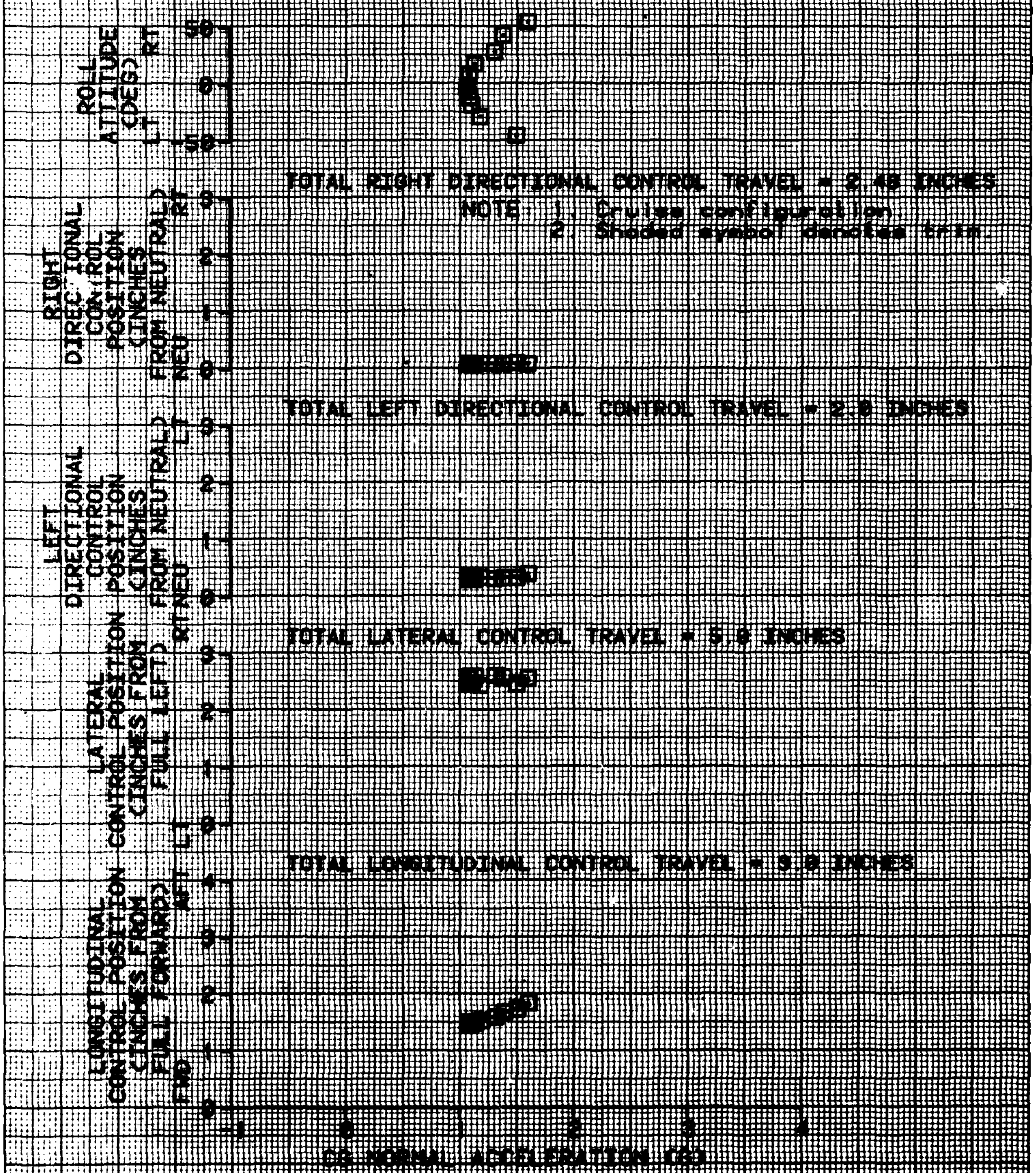


FIGURE 30

PULLUPS AND PUSHOVERS

LONG-EZ USA S/N 82-1248 (N1263)

GROSS WEIGHT (POUNDS)	LONGITUDINAL CG LOCATION (FS)	DENSITY ALTITUDE (FEET)	OAT (DEG C)	CONFIGURATION
1248	103.7(AFT)	9448	8.5	CRUISE

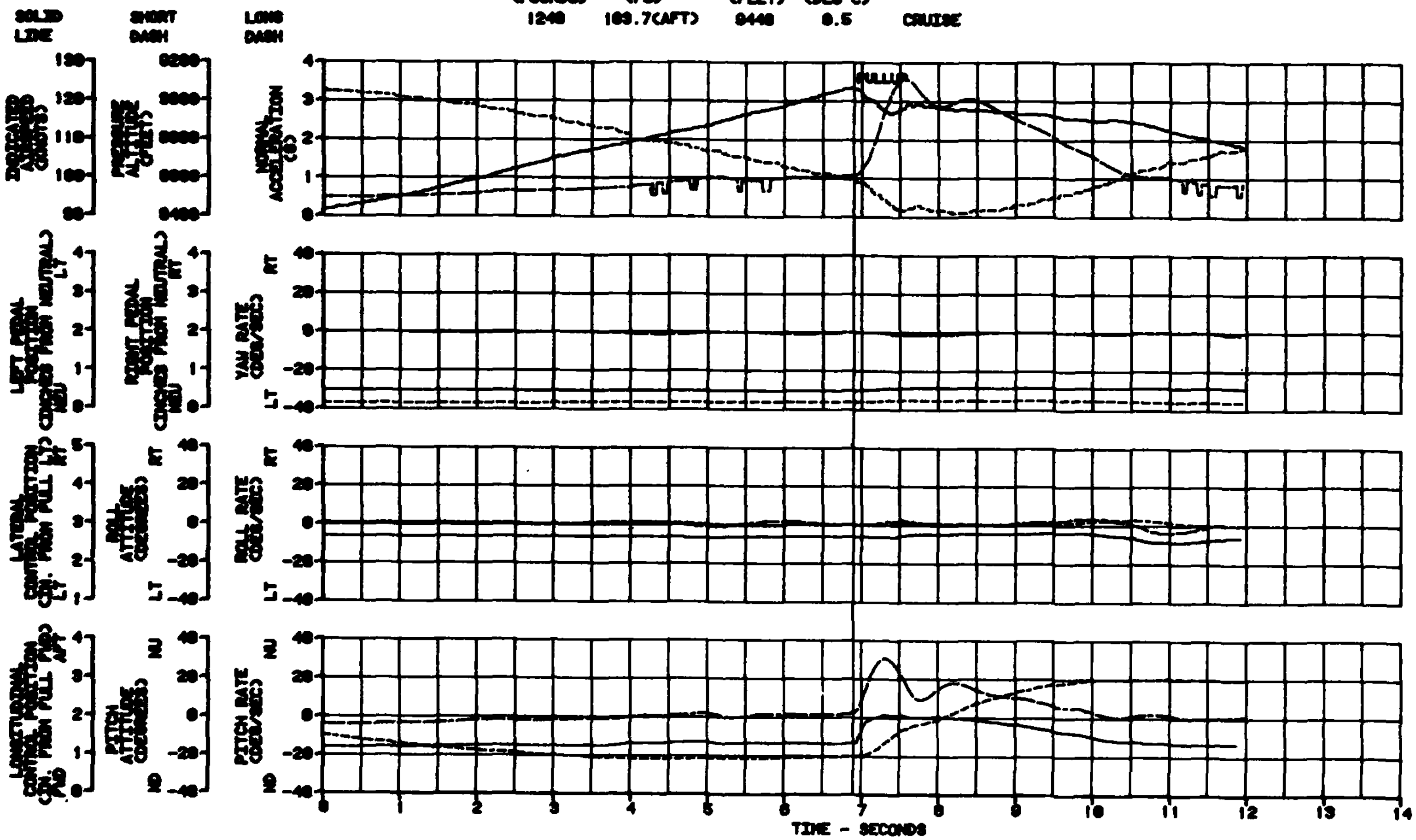


FIGURE 31
PULLUPS AND PUSHOVERS
LONG-EZ USA S/N 82-1240 (N1263)

GROSS WEIGHT (POUNDS)	LONGITUDINAL CG LOCATION (FS)	DENSITY ALTITUDE (FEET)	OAT (DEG C)	CONFIGURATION
1240	103.0(AFT)	[illegible]	3.0	CRUISE

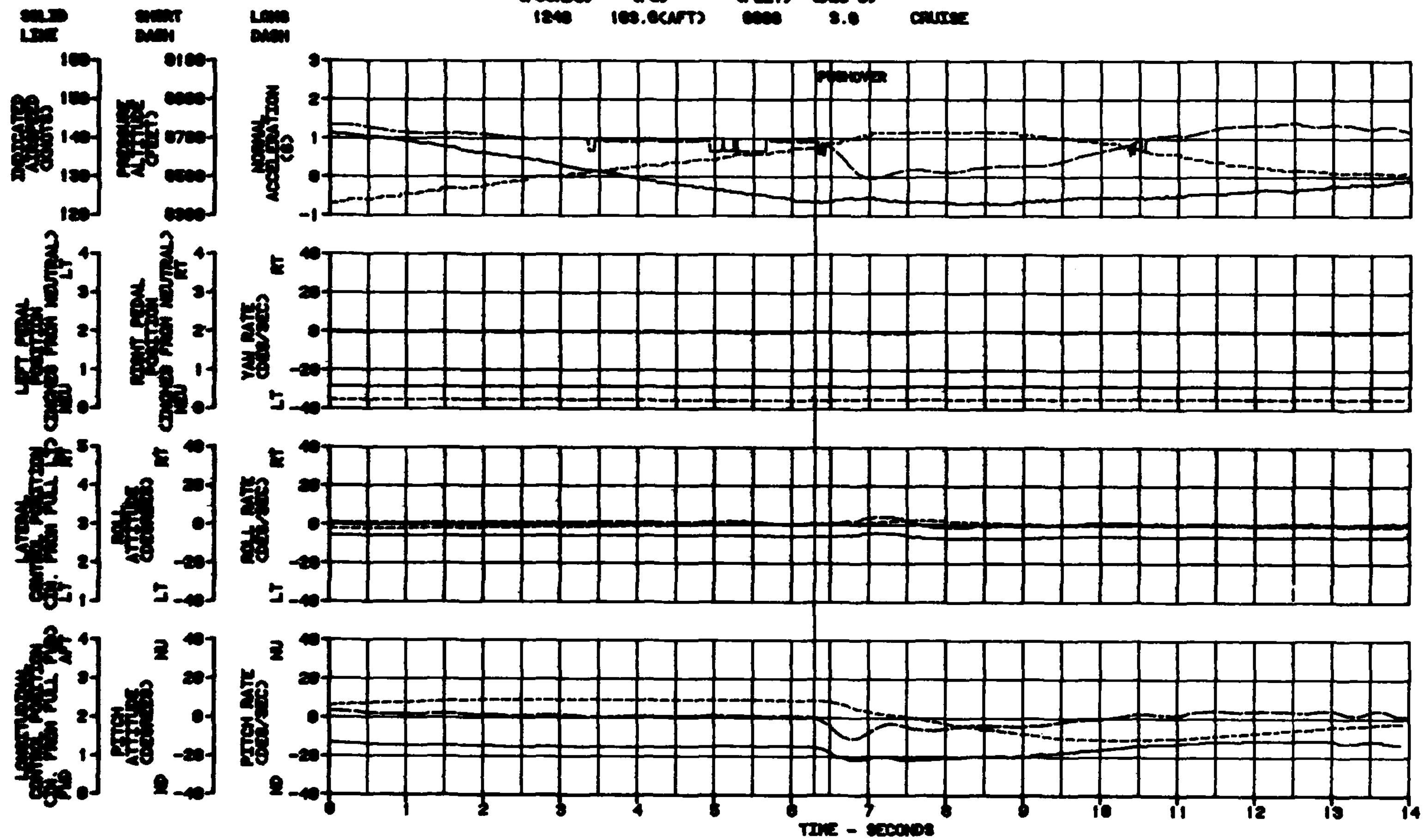


FIGURE 32
DYNAMIC STABILITY
LONG-EZ USA S/N 82-1240 (N1253)

GROSS WEIGHT (POUNDS)	LONGITUDINAL CG LOCATION (FS)	DENSITY ALTITUDE (FEET)	OAT (DEG C)	CONFIGURATION
1210	103.8(AFT)	10300	-0.5	CRUISE

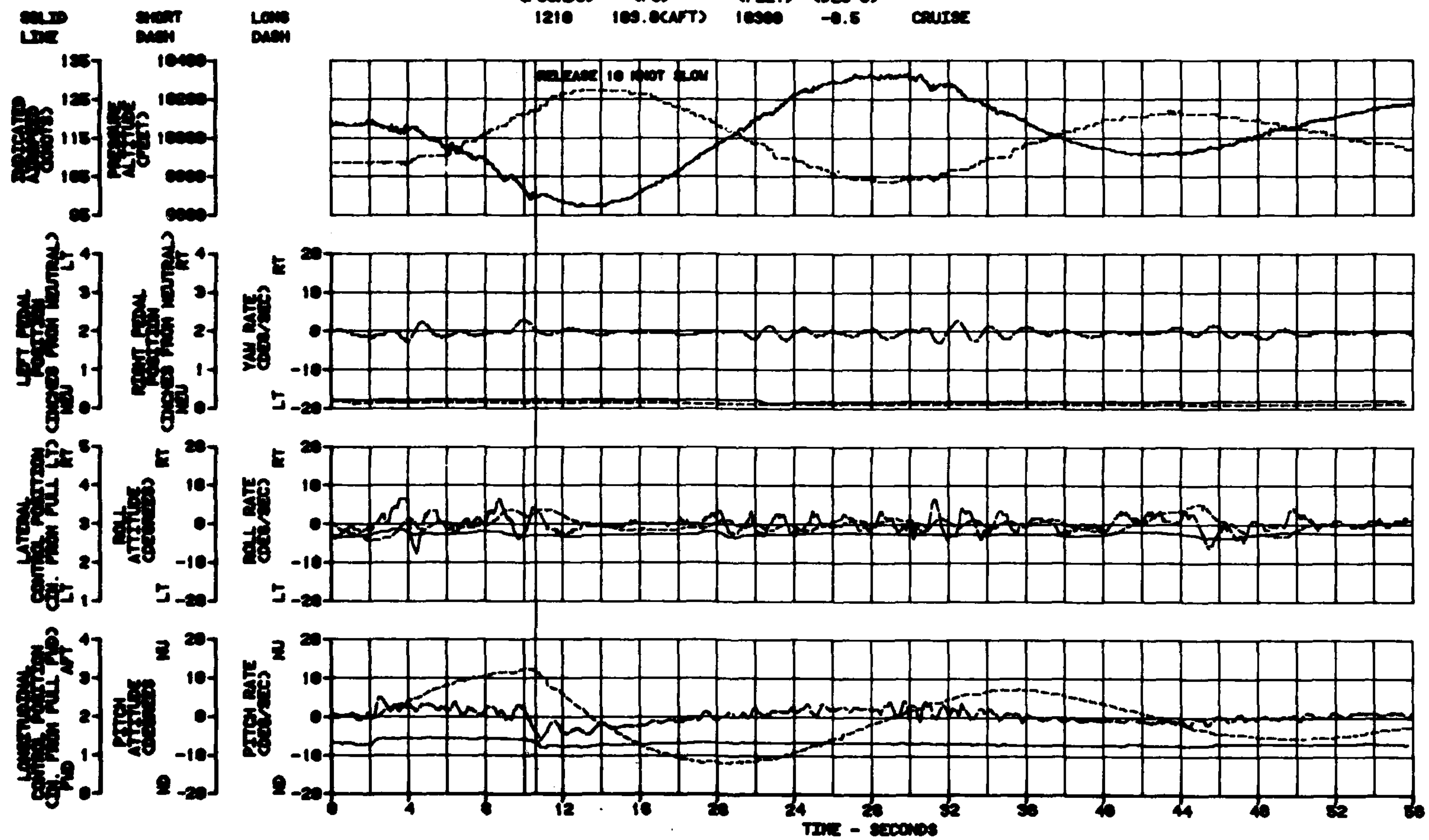


FIGURE 33
DYNAMIC STABILITY
LONG-EZ USA S/N 82-1240 (N1253)

GROSS WEIGHT (POUNDS)	LONGITUDINAL CG LOCATION (FS)	DENSITY ALTITUDE (FEET)	OAT (DEG C)	CONFIGURATION
1220	103.0(AFT)	9400	-2.5	CRUISE

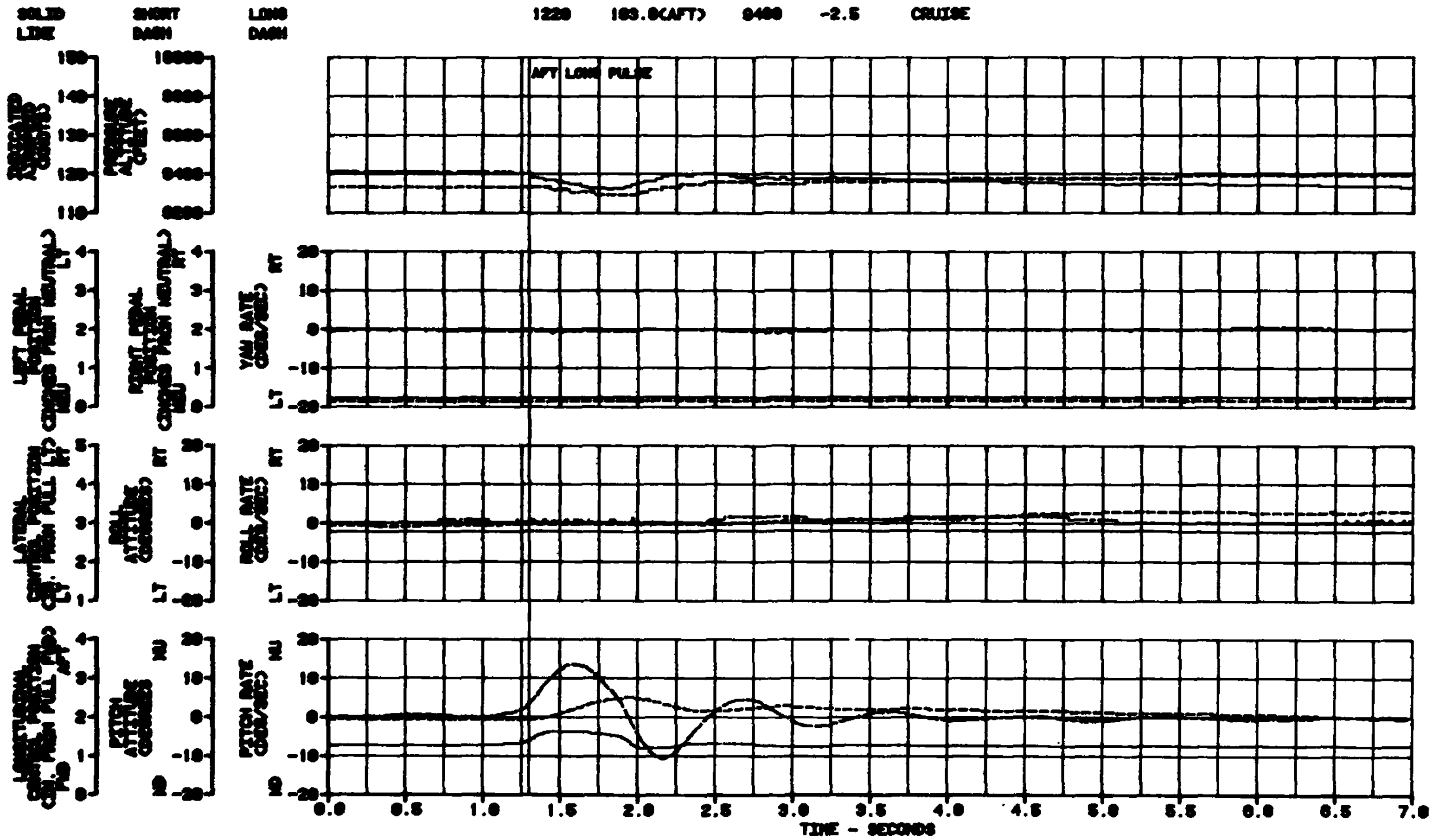
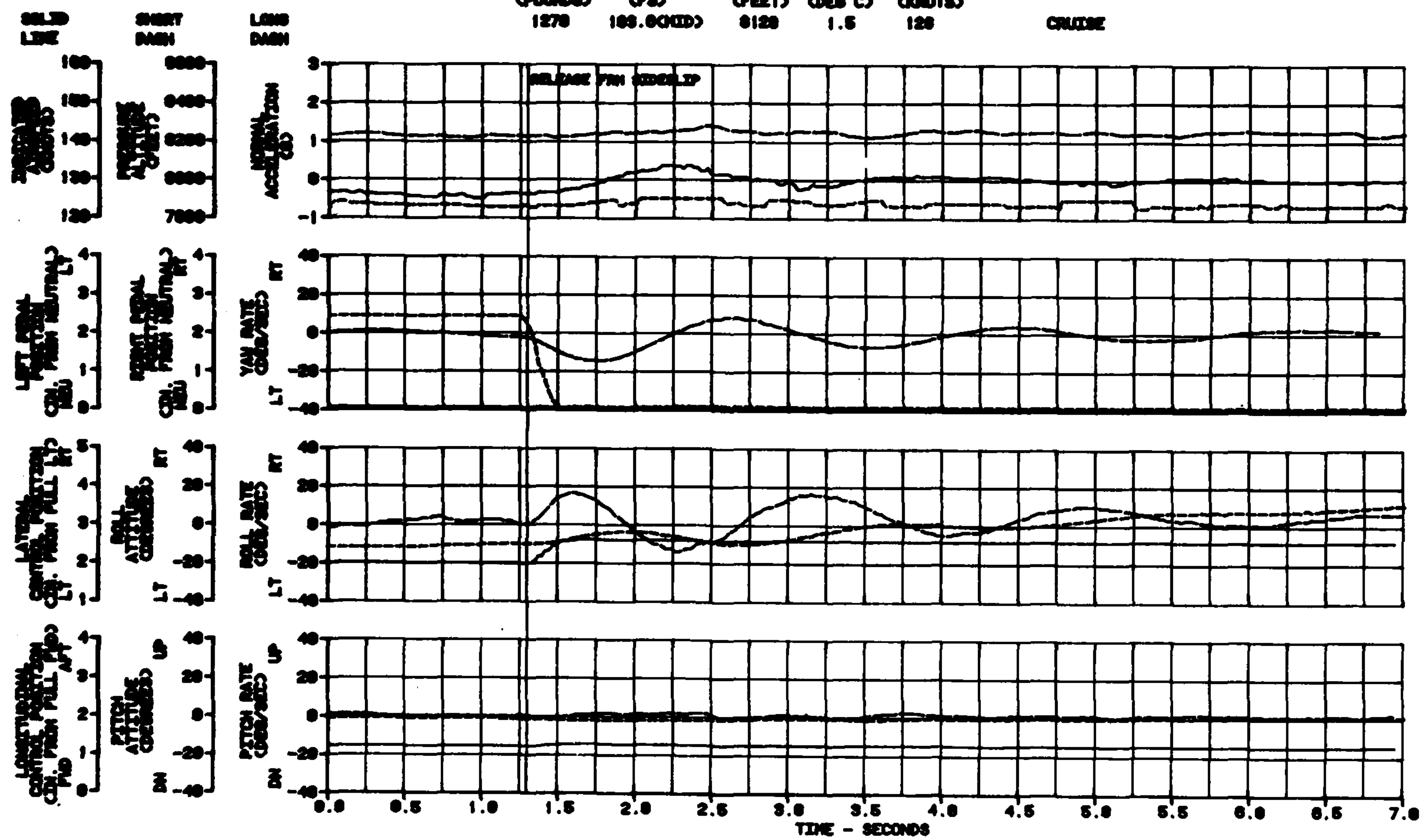


FIGURE 34
RELEASE FROM SIDESLIP
LONG-EZ USA S/N 82-1240 (N1253)

GROSS WEIGHT (POUNDS)	LONGITUDINAL CG LOCATION (FS)	DENSITY ALTITUDE (FEET)	OAT (DEG C)	CALIBRATED AIRSPEED (KNOTS)	CONFIGURATION
1270	160.0(MID)	8120	1.5	120	CRUISE



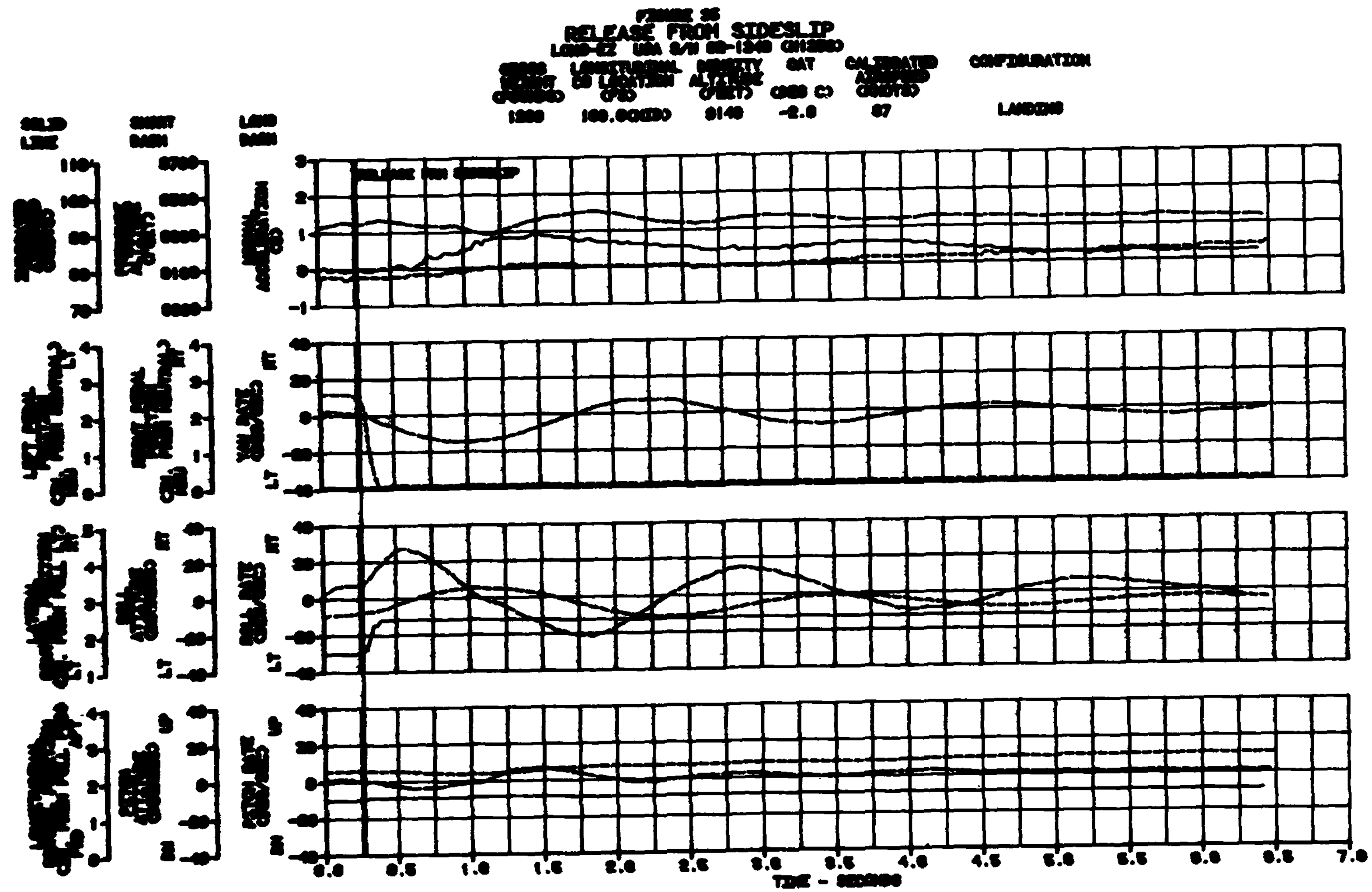

RELEASE FROM SIDESLIP
OAT
CONFIGURATION
LANDING
TIME - SECONDS

FIGURE 36
GUST RESPONSE
LONG-EZ USA S/N 82-1240 (N1253)

GROSS WEIGHT (POUNDS)	LONGITUDINAL CG LOCATION (FS)	DENSITY ALTITUDE (FEET)	OAT (DEG C)	CONFIGURATION
1100	100.7(MID)	2000	8.5	CRUISE

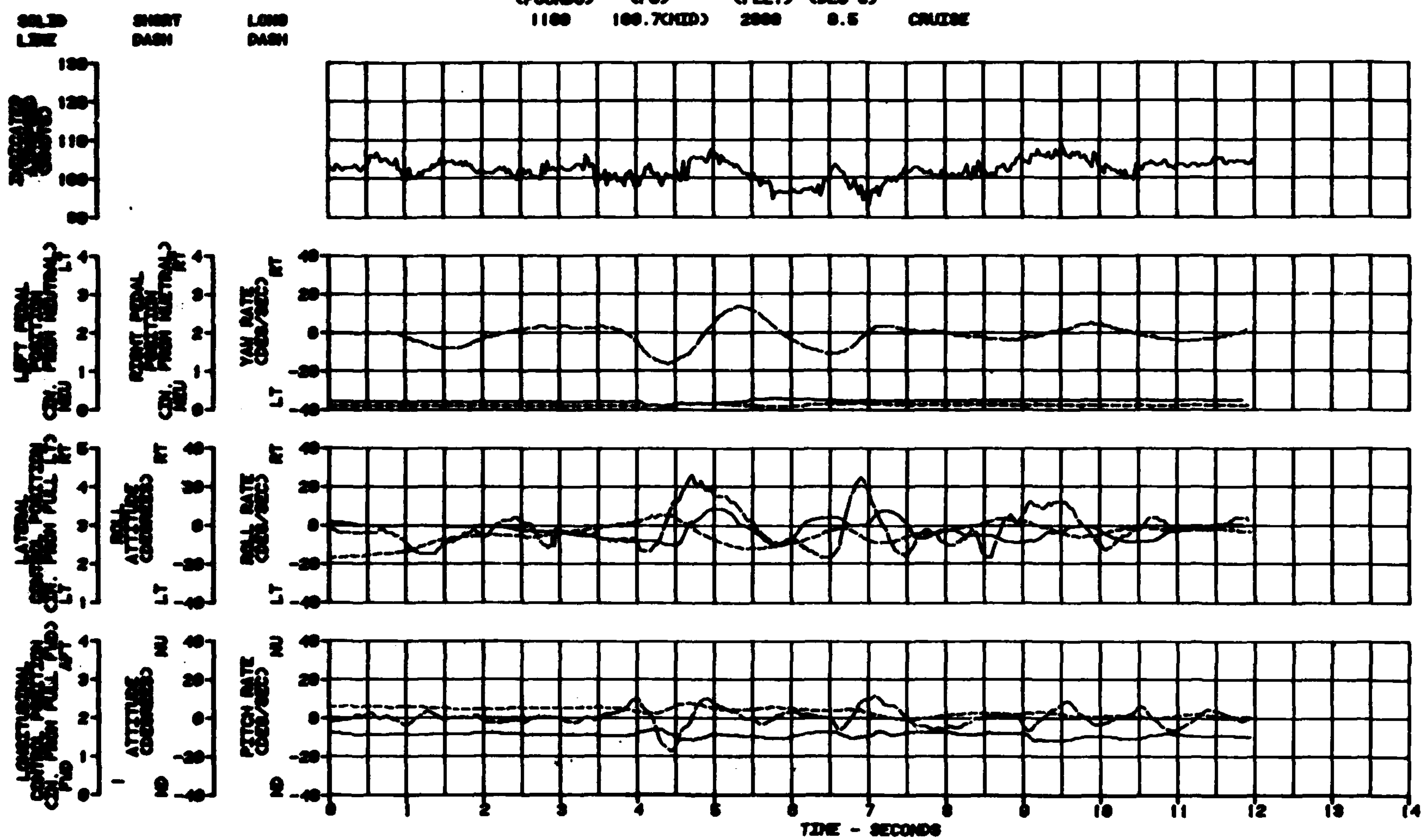


FIGURE 37
ROLL CONTROL EFFECTIVENESS
LONG-EZ USA S/N 82-1240 (N1253)

GROSS WEIGHT (POUNDS)	LONGITUDINAL CG LOCATION (FS)	DENSITY ALTITUDE (FEET)	OAT (DEG C)	CONFIGURATION	TRIM CALIBRATED AIRSPEED (KNOTS)
1230	100.0(AFT)	8200	1.5	CRUISE	125

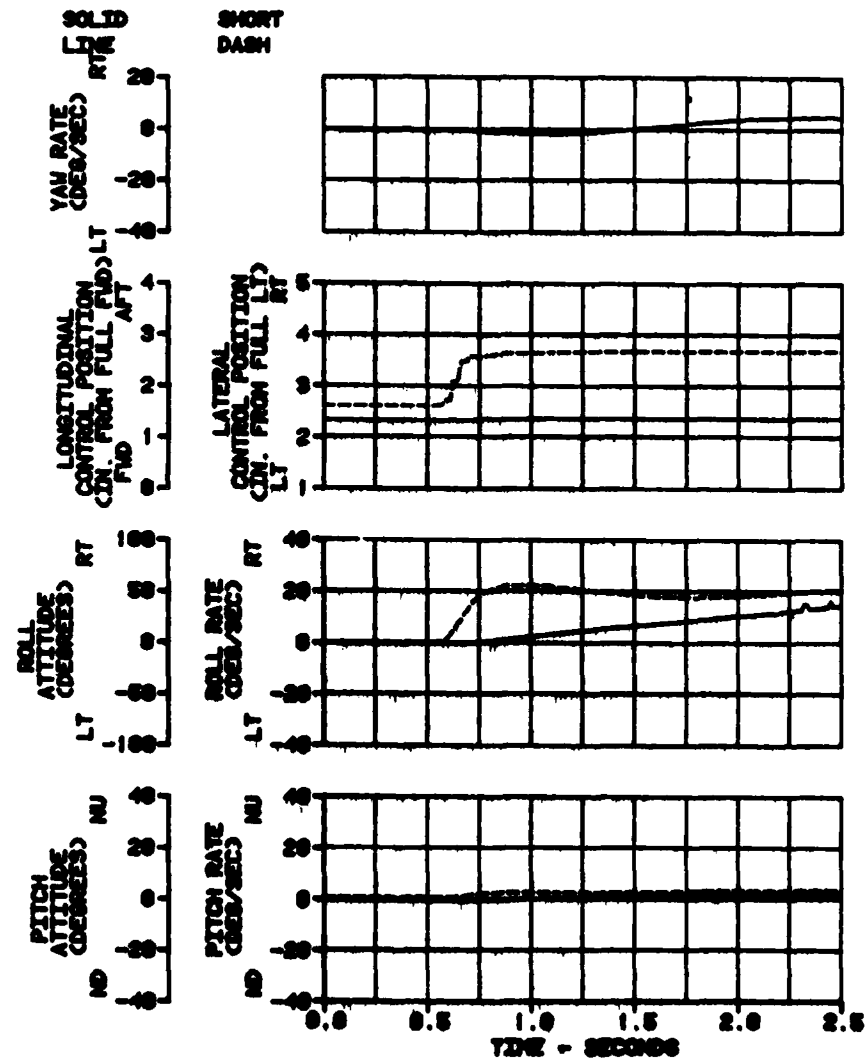


FIGURE 30

ROLL CONTROL EFFECTIVENESS

LONG-EZ USA S/N 82-1240 (N1253)

GROSS WEIGHT (POUNDS)	LONGITUDINAL CG LOCATION (FS)	DENSITY ALTITUDE (FEET)	OAT (DEG C)	CONFIGURATION	TRIM CALIBRATED AIRSPEED (KNOTS)
1290	103.0(AFT)	7000	-0.5	CRUISE	110

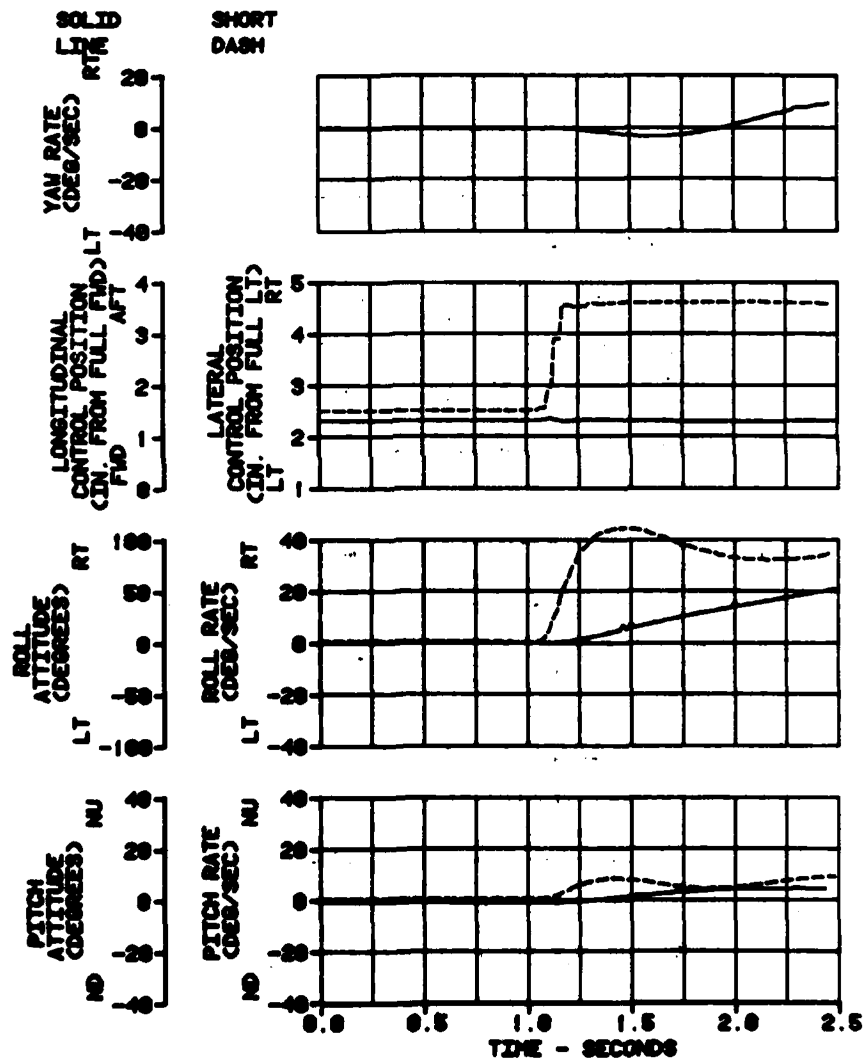


FIGURE 30
ROLL CONTROL EFFECTIVENESS
LONG-EZ USA S/N 82-1240 (N1253)

GROSS WEIGHT (POUNDS)	LONGITUDINAL CG LOCATION (FS)	DENSITY ALTITUDE (FEET)	OAT (DEG C)	CONFIGURATION	TRIM CALIBRATED AIRSPEED (KNOTS)
1290	103.0(AFT)	7820	0.0	CRUISE	121

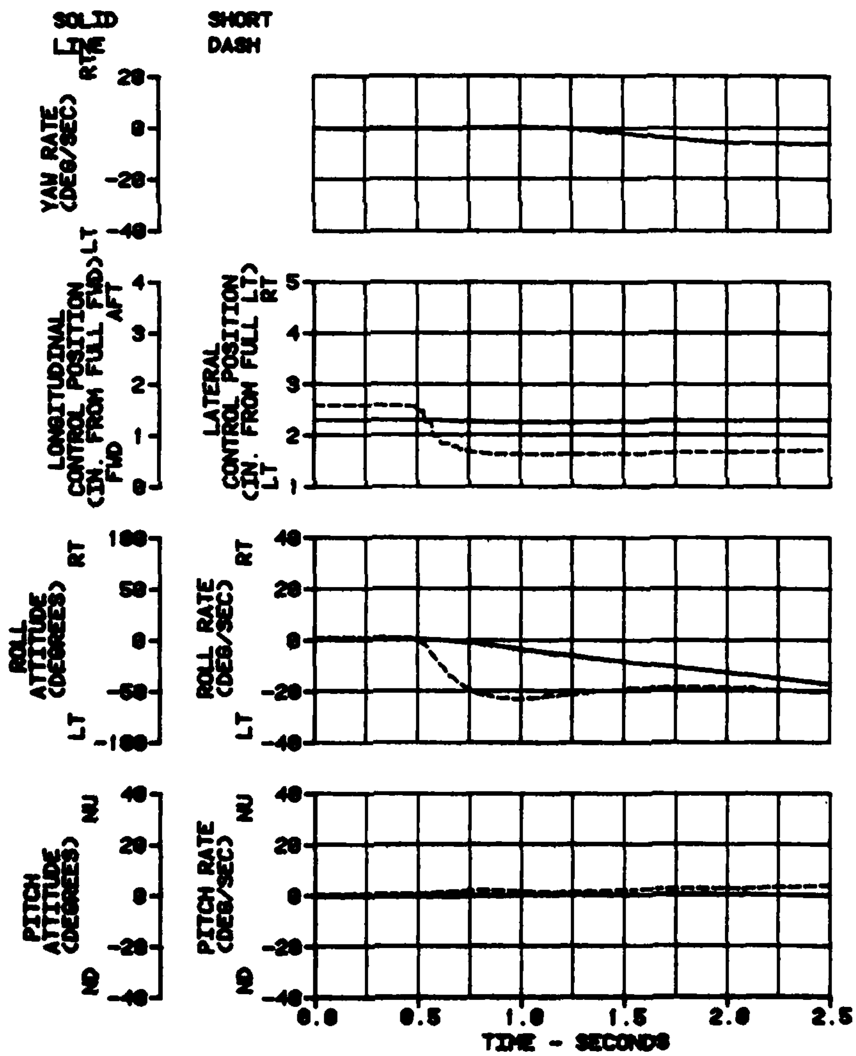
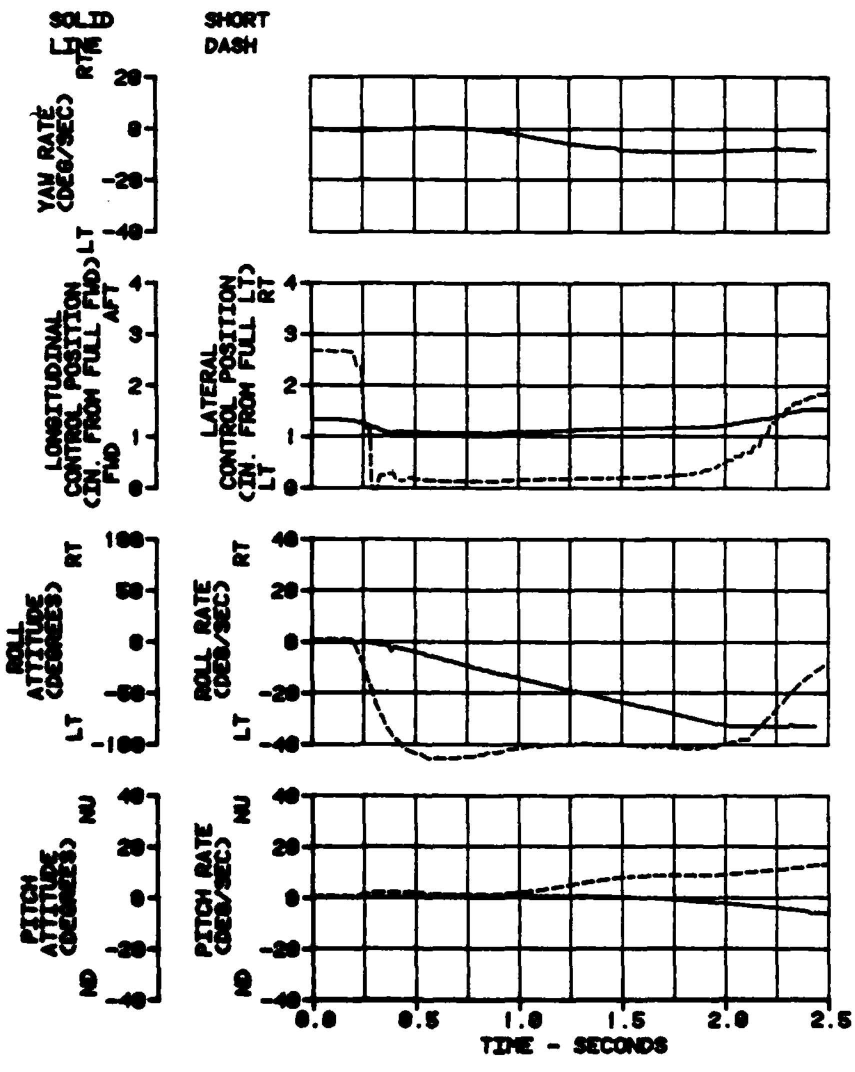


FIGURE 40

ROLL CONTROL EFFECTIVENESS

LONG-EZ USA S/N 82-1240 (N1253)

GROSS WEIGHT (POUNDS)	LONGITUDINAL CG LOCATION (FS)	DENSITY ALTITUDE (FEET)	OAT (DEG C)	CONFIGURATION	TRIM CALIBRATED AIRSPEED (KNOTS)
1230	103.0(AFT)	7600	-0.5	CRUISE	121



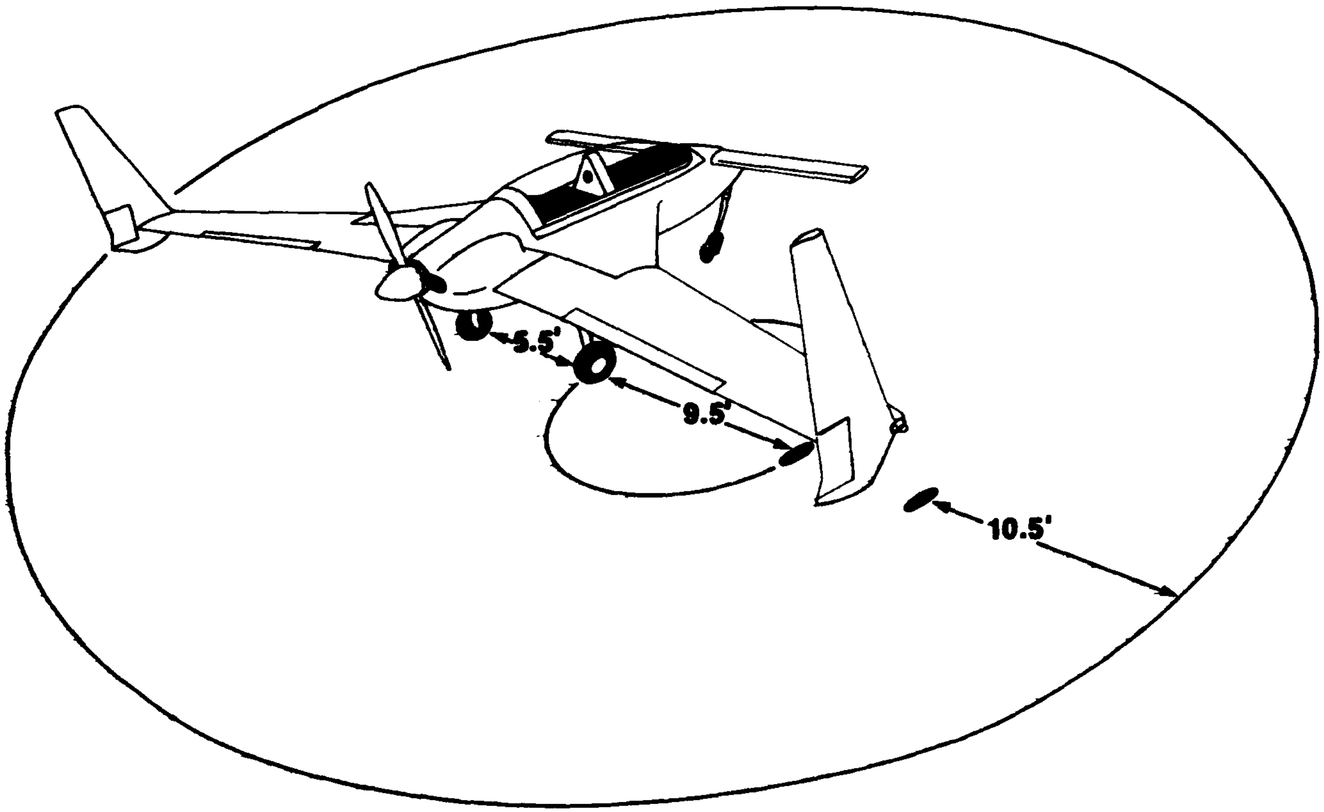


Figure 41. Turn Radius

FIGURE 42
VIBRATION SPECTRUM
WING SPAR
LONG-EZ USA S/N 82-1240 (N1253)
IN-FLIGHT VIBRATIONS

CALIBRATED AIRSPEED (KNOTS)	GROSS WEIGHT (POUNDS)	LONGITUDINAL CG LOCATION (FS)	DENSITY ALTITUDE (FEET)	OAT (DEG C)	CONFIGURATION	PROPELLER SPEED (RPM)
102	1250	101.9 (MID)	7180	4.5	CRUISE	1692

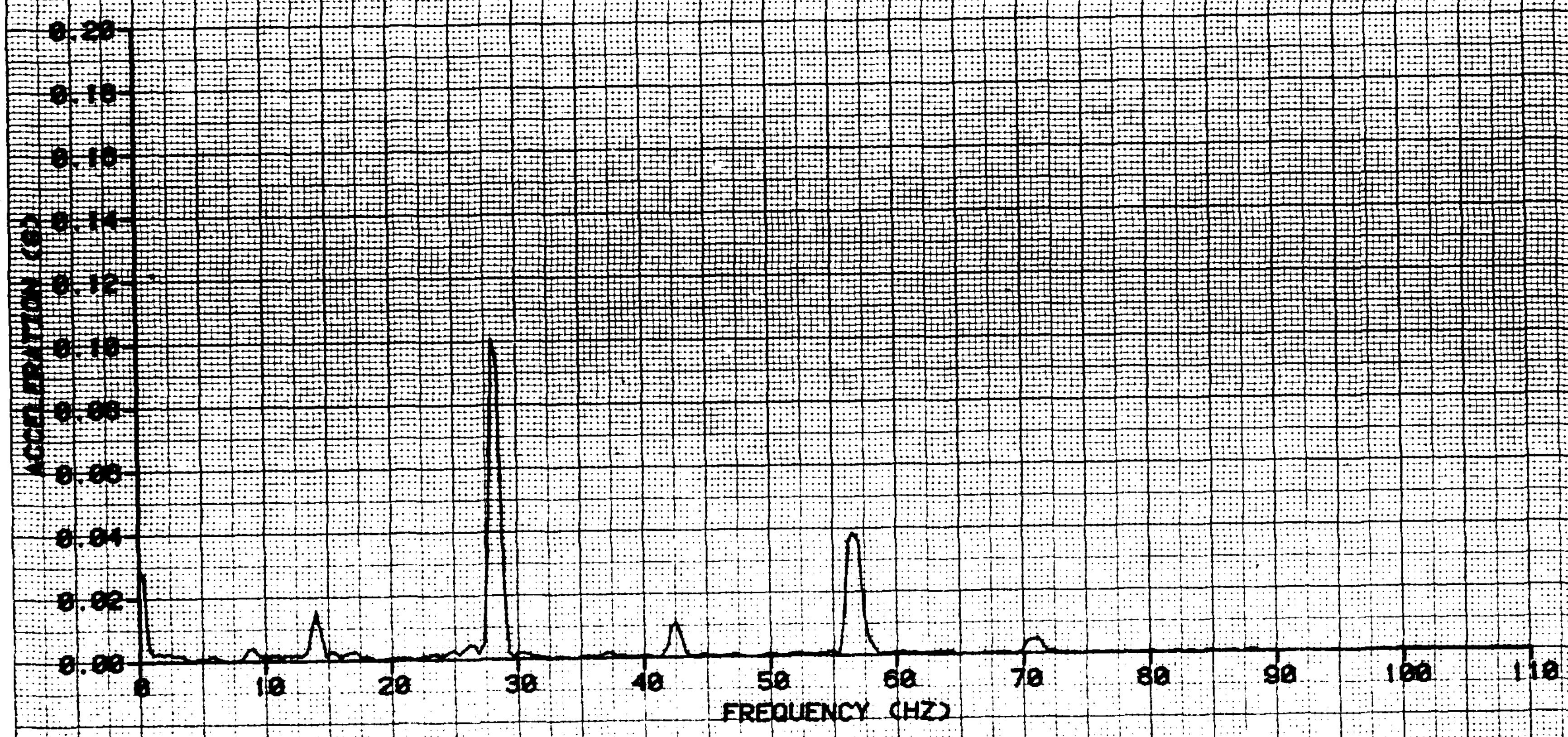


FIGURE 43
VIBRATION CHARACTERISTICS
WING SPAR
LONG-EZ USA S/N 82-1240 (N1283)
IN-FLIGHT VIBRATIONS

CALIBRATED AIRSPEED (KNOTS)	GROSS WEIGHT (POUNDS)	LONGITUDINAL CG LOCATION (FS)	DENSITY ALTITUDE (FEET)	OAT (DEG C)	CONFIGURATION
100	1250	101.9 (MID)	8500	2.5	CRUISE

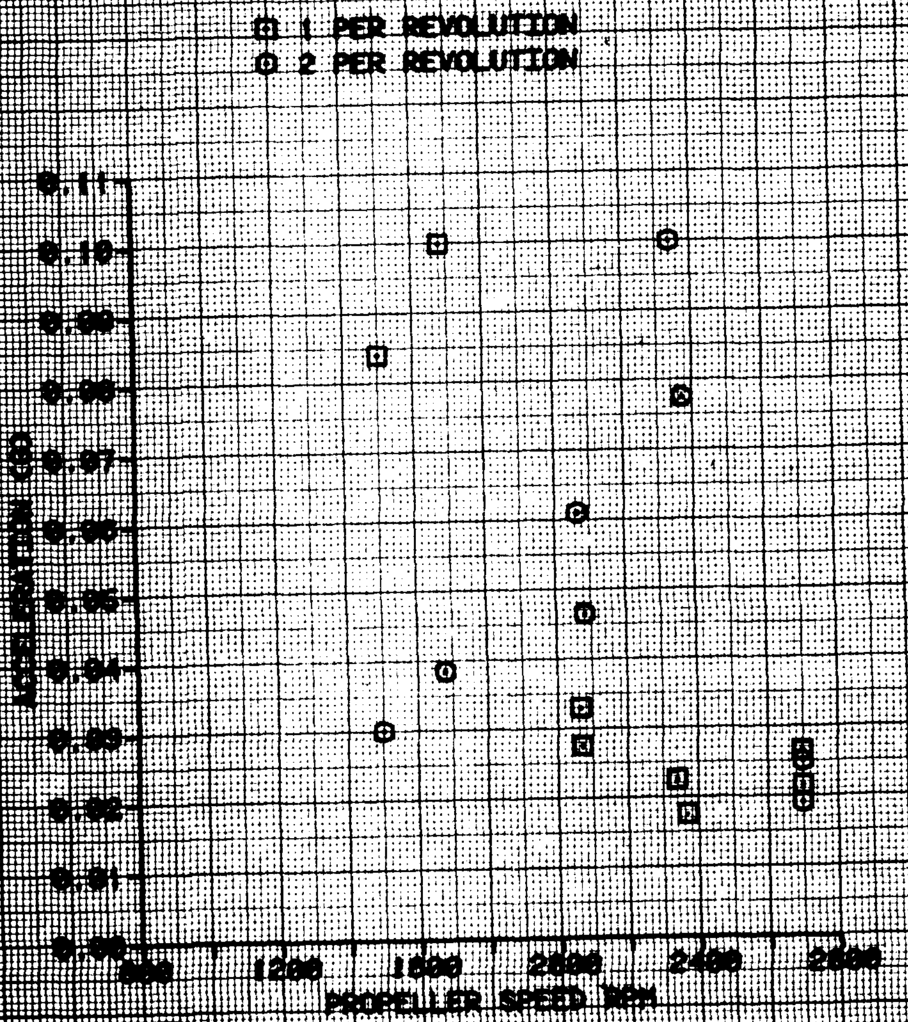
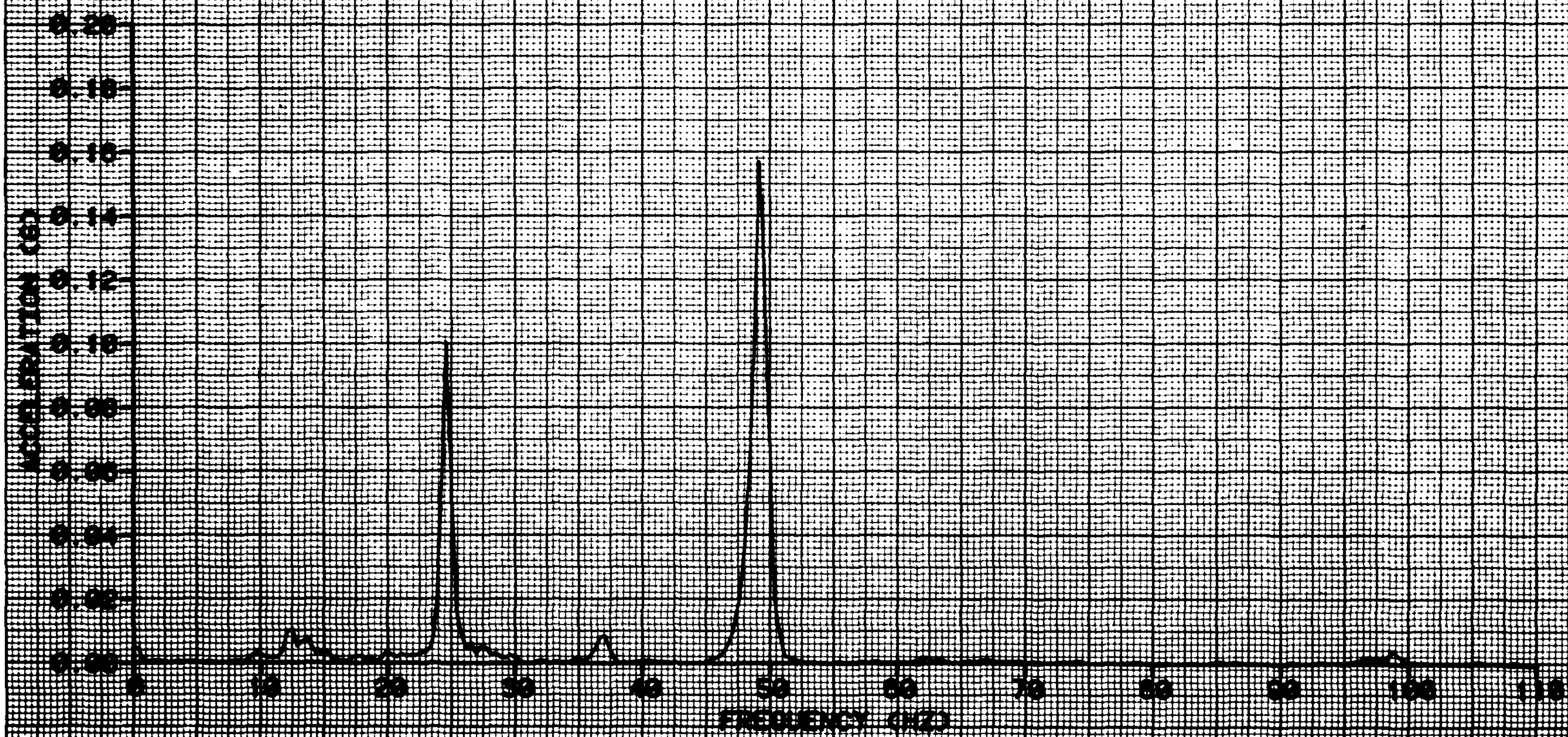


FIGURE 44
VIBRATION SPECTRUM
WING SPAR
LONG-EZ USA S/N 82-1240 (N1253)
GROUND VIBRATIONS

GROSS WEIGHT (POUNDS)	LONGITUDINAL CG LOCATION (FS)	PROPELLER SPEED (RPM)
1280	102.0 (MID)	1470



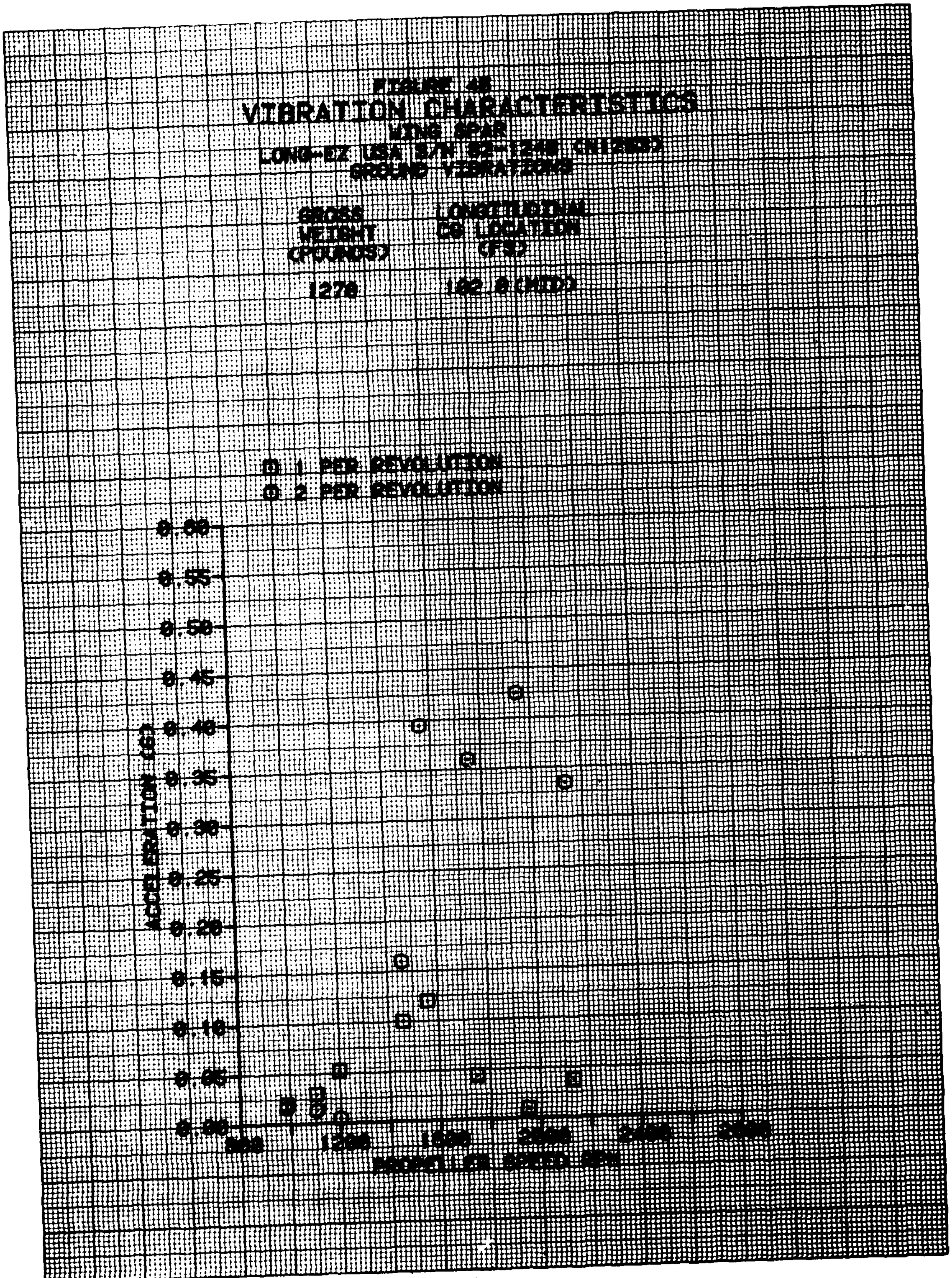

VIBRATION CHARACTERISTICS
WING SPAR
LONG-EZ USA
GROUND VIBRATIONS
GROSS WEIGHT (POUNDS)
LONGITUDINAL CG LOCATION (FS)
1278
(MID)
1 PER REVOLUTION
2 PER REVOLUTION
0.60
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
ACCELERATION (G)
800
1200
1600
2000
2400
2800
PROPELLER SPEED RPM

FIGURE 46
AILERON BUFFET EVALUATION
LONG-EZ USA S/N 82-1240 (N1253)

GROSS WEIGHT (POUNDS)	LONGITUDINAL CG LOCATION (FS)	DENSITY ALTITUDE (FEET)	OAT (DEG C)	CONFIGURATION
1250	103.9(AFT)	10300	-1.6	CRUISE

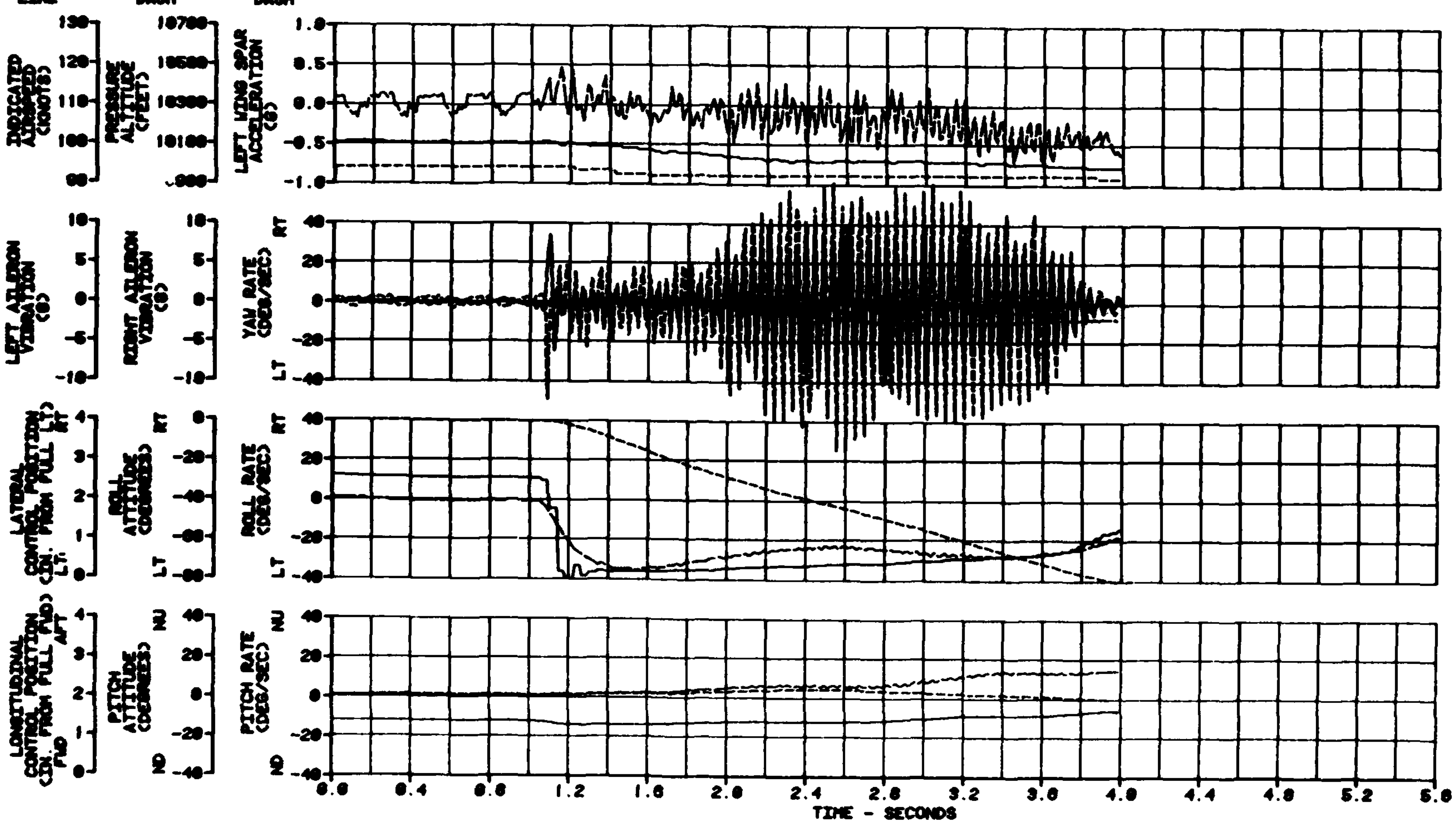
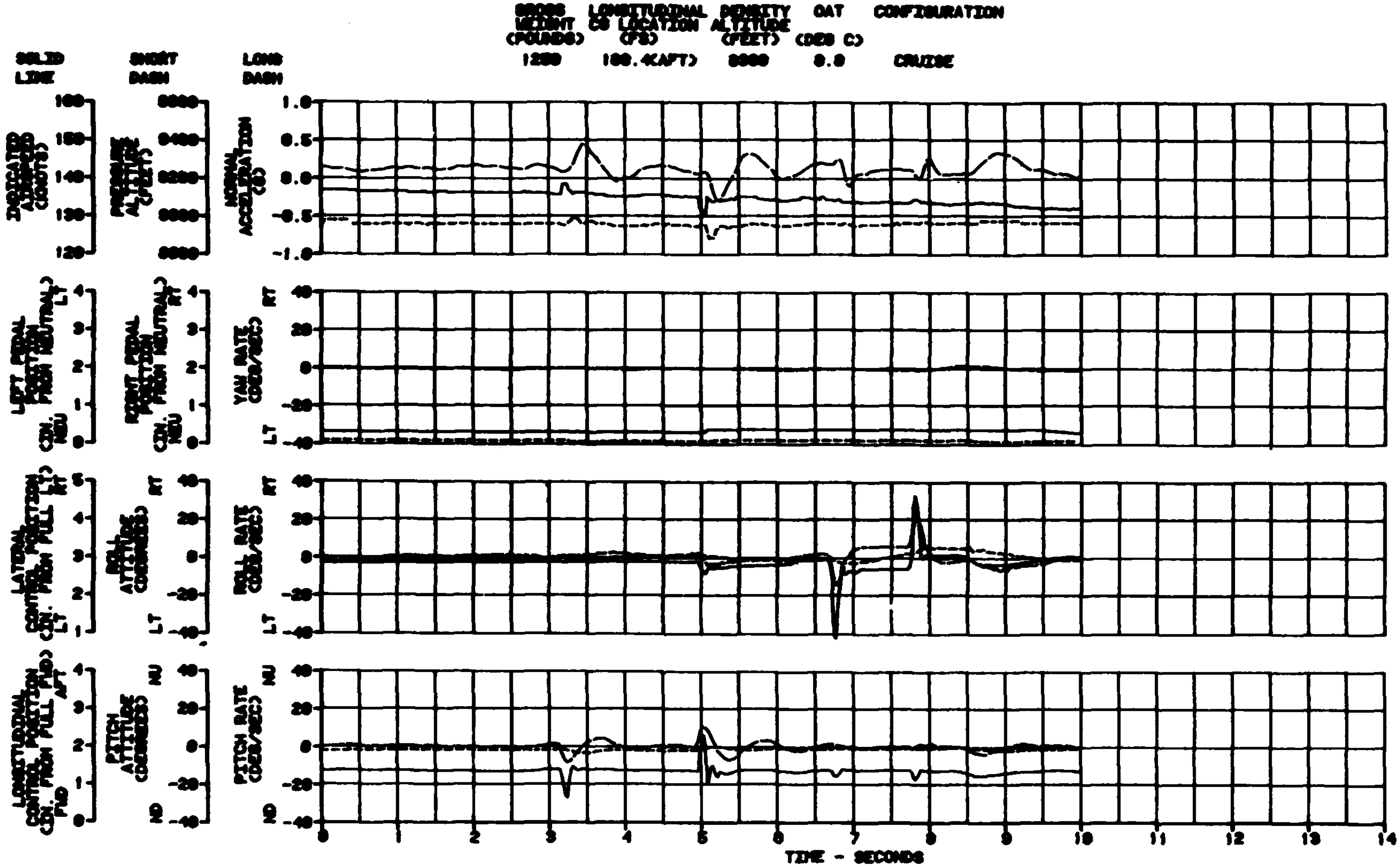


FIGURE 47
STICK RAPS
LONG-EZ USA S/N 88-1240 (N1253)



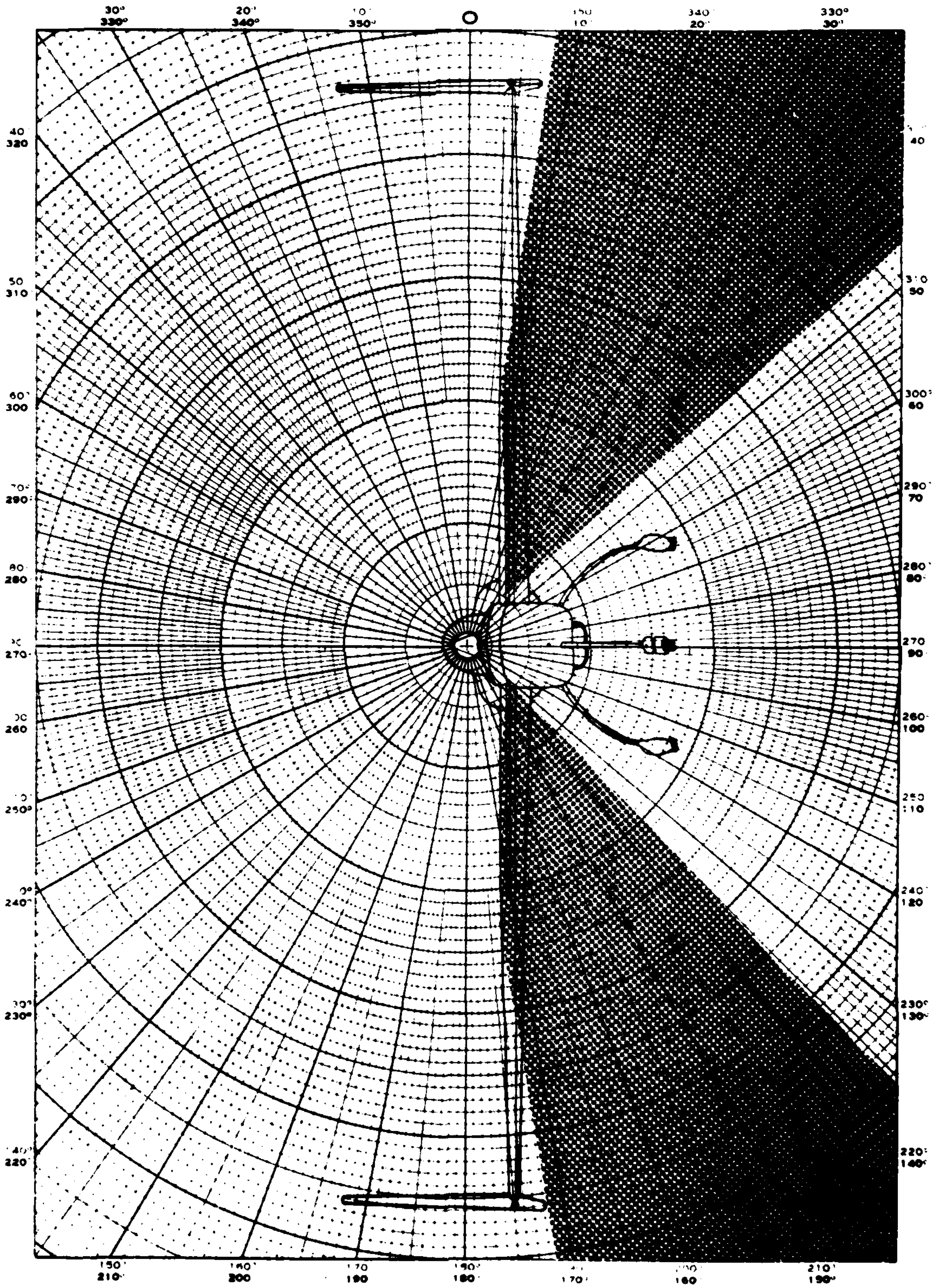


Figure 48. Vertical Field-of-View

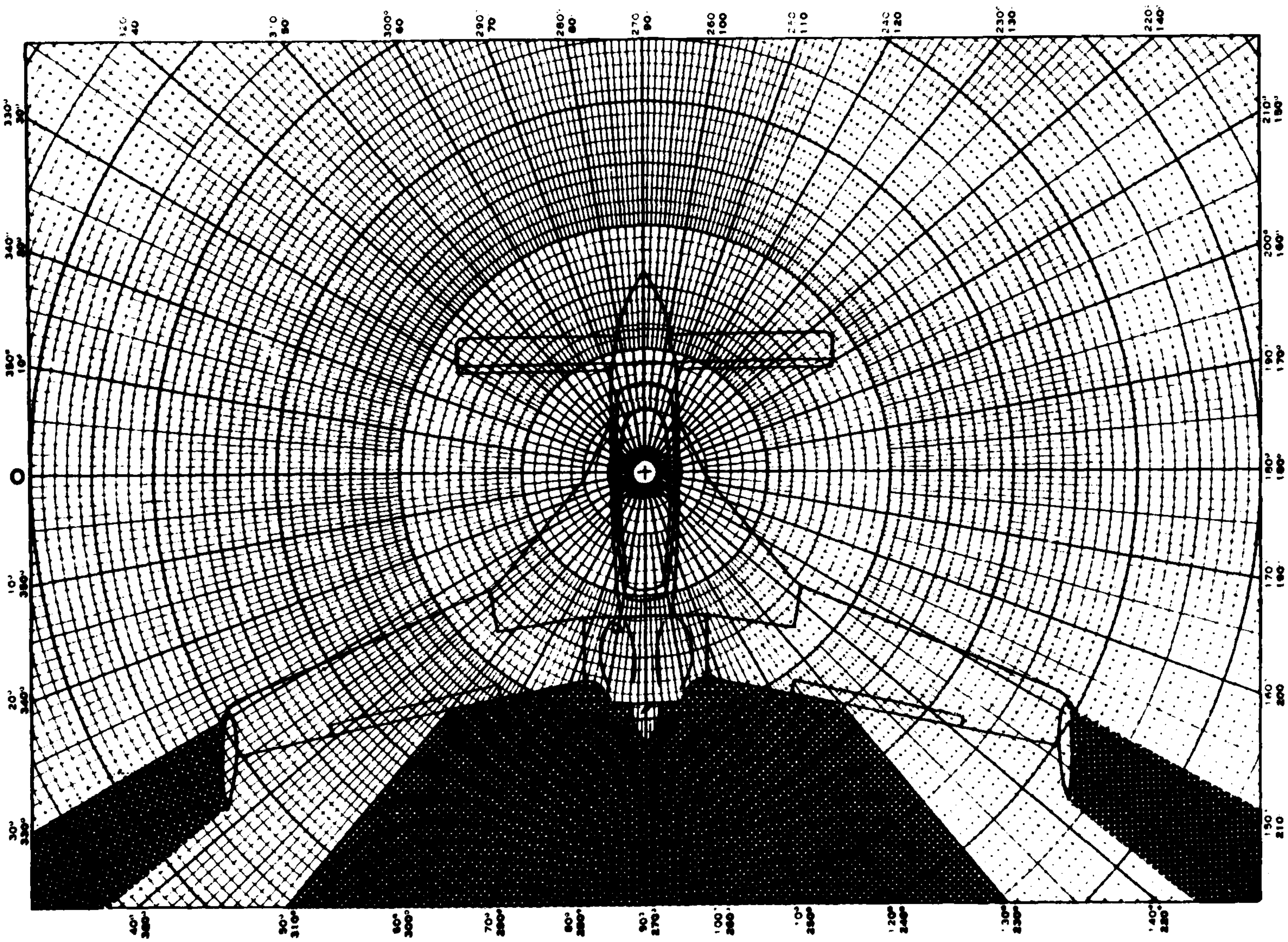


Figure 49. Lateral Field-of-View

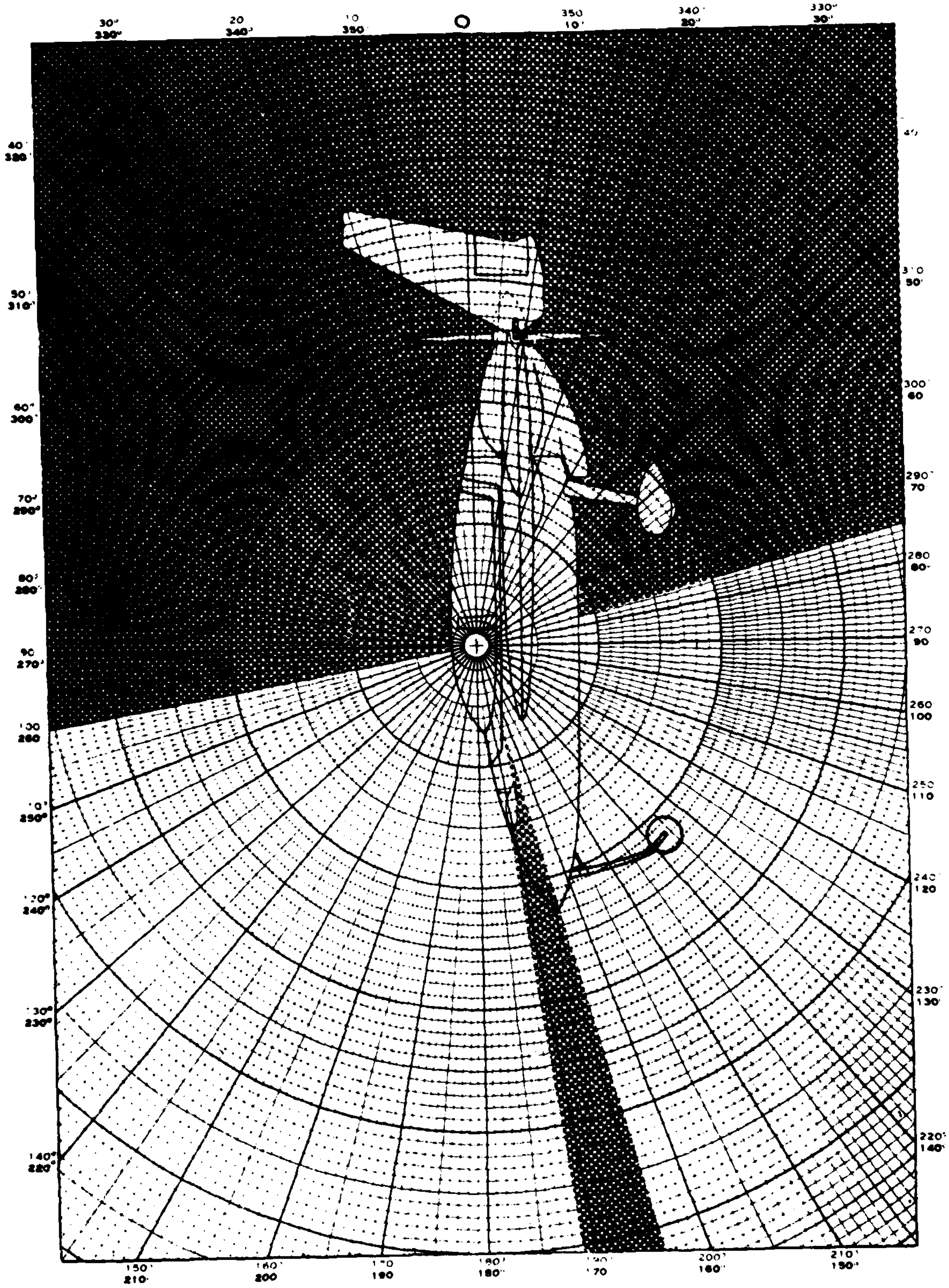
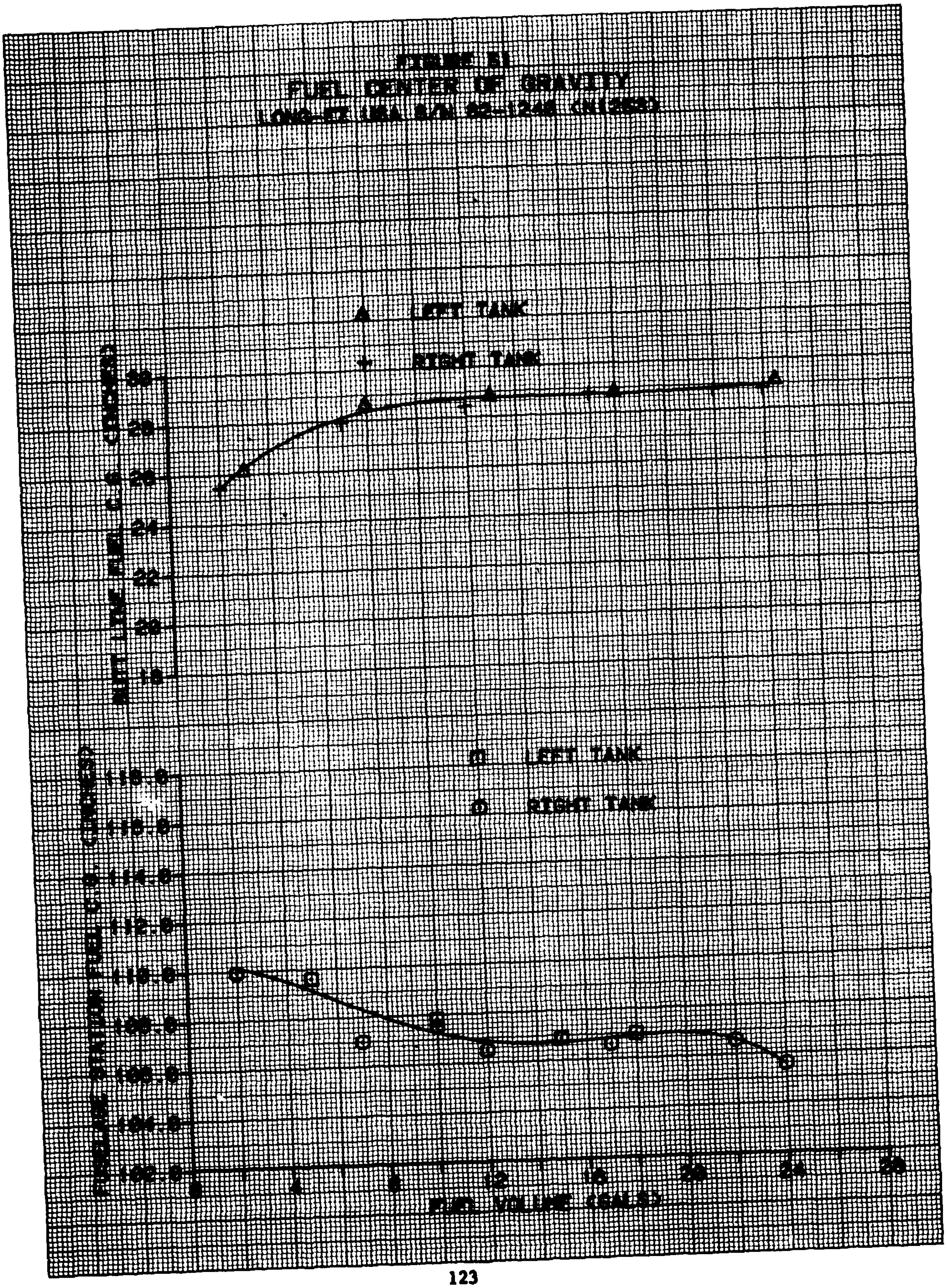


Figure 50. Longitudinal Field-of-View


FUEL CENTER OF GRAVITY
LEFT TANK
RIGHT TANK
BUTT LINE FUEL C.G. (INCHES)
30
28
26
24
22
20
18
LEFT TANK
RIGHT TANK
FUSELAGE STATION FUEL C.G. (INCHES)
118.0
116.0
114.0
112.0
110.0
108.0
106.0
104.0
102.0
0
4
8
12
16
20
24
28
FUEL VOLUME (GALS)

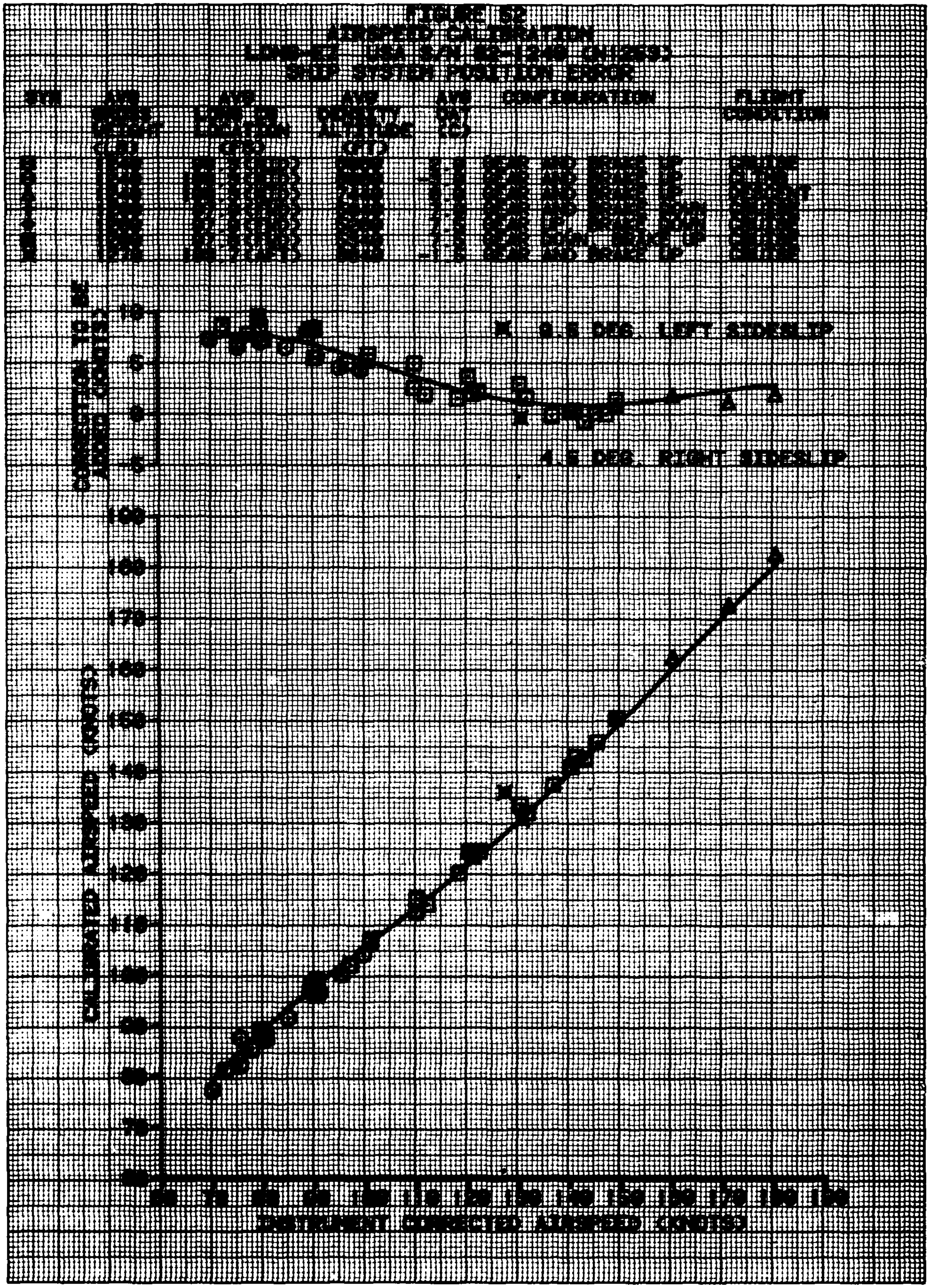


FIGURE 52
AIRSPEED CALIBRATION
CONFIGURATION
9.5 DEG. LEFT SIDESLIP
4.5 DEG. RIGHT SIDESLIP
INSTRUMENT CORRECTED AIRSPEED (KNOTS)

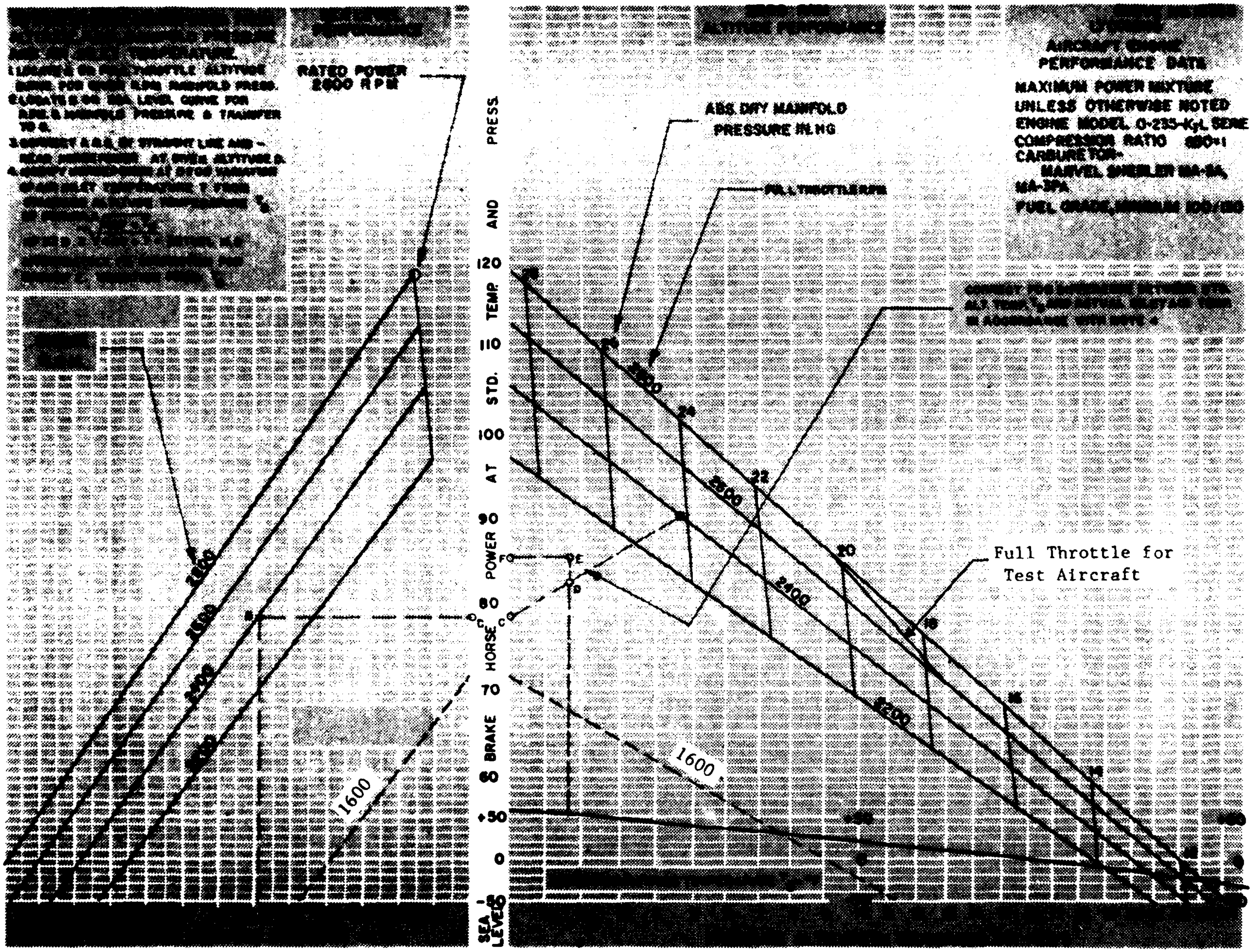


Figure 53. Power Available

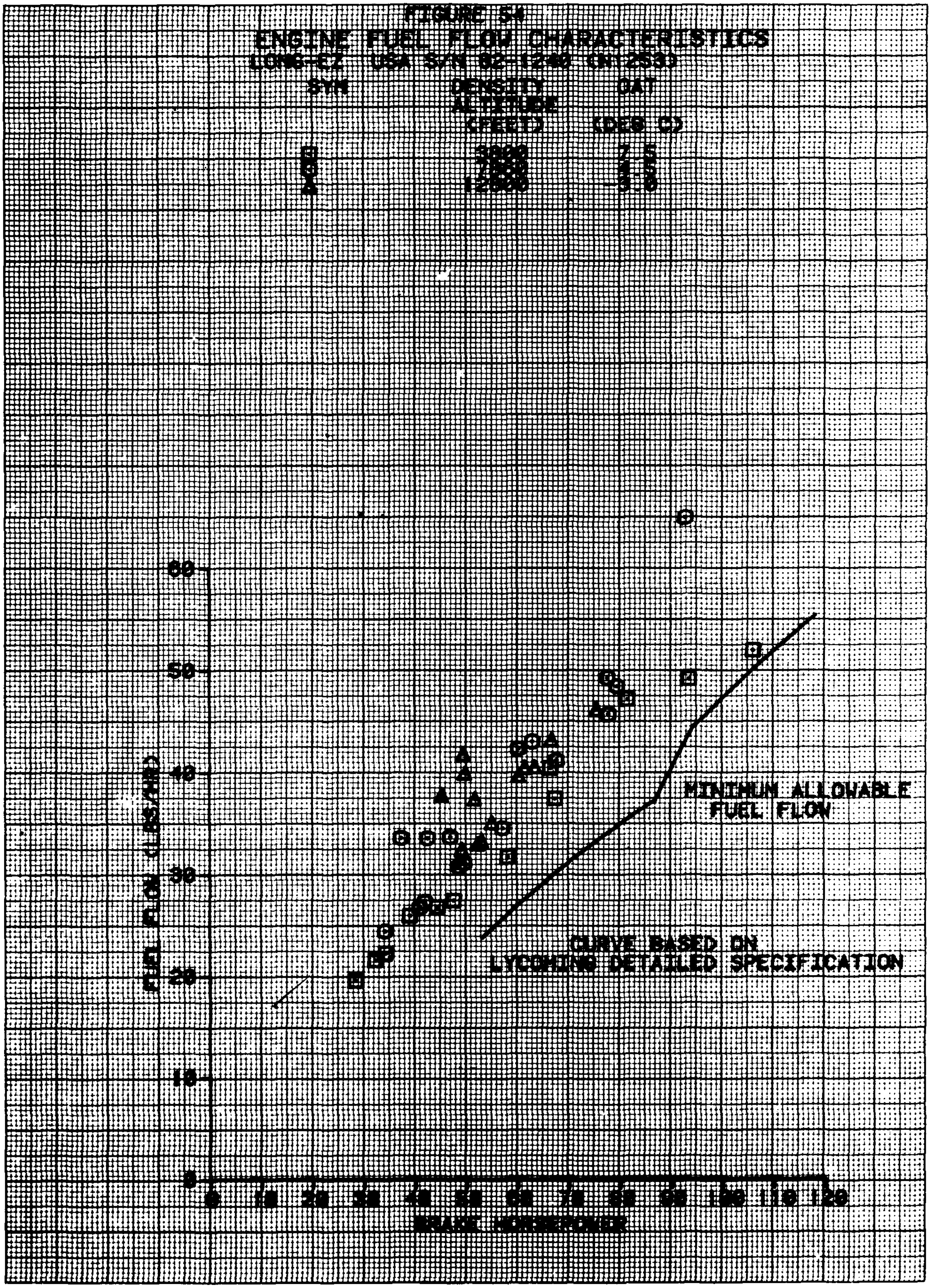


FIGURE 54
ENGINE FUEL FLOW CHARACTERISTICS
LONG-EZ USA S/N 82-1240 (N1253)
SYM
DENSITY ALTITUDE (FEET)
OAT (DEG C)
FUEL FLOW (LBS/HR)
BRAKE HORSEPOWER
0
10
20
30
40
50
60
70
80
90
100
110
120
MINIMUM ALLOWABLE FUEL FLOW
CURVE BASED ON LYCOMING DETAILED SPECIFICATION

APPENDIX F. STRUCTURAL LOAD VERIFICATION TEST

DRDAV-DS

MEMORANDUM THRU CHIEF STRUCTURES & MATERIALS DIV
DEPUTY DIRECTOR ———— 8 Feb 83

FOR: DIRECTOR OF DEVELOPMENT & QUALIFICATION

SUBJECT: Trip to AEFA, Edwards Air Force Base, CA, on 16 through 19 Jan 83

1. Purpose: To proof test the Long-EZ aircraft prior to issuance of airworthiness release.

2. Itinerary: St. Louis, MO to AEFA, Edwards AFB, CA and return to St. Louis, MO.

3. Individuals Contacted:

Mr. Vern Diekman	AEFA	AV 350-4986
MAJ Don Underwood	AEFA	AV 350-4787
Mr. John Johnson	AEFA	AV 350-4786
MAJ Kreutz	Ft. Lewis, WA	AV 357-6327

4. Inclosure: Test Data and Results.

5. Discussion: The Long EZ is a homebuilt aircraft from a kit designed by Mr. Burt Rutan, Rutan Aircraft Factory Inc., Mojave, CA. This particular aircraft was built by aircraft section, Ft. Lewis, WA. The basic design of the aircraft has been tested and proven to FAA standards, and at least 16 aircraft of this design are flying. The main concern, is one of quality control during construction thus necessitating the proof tests. It is felt that proof testing the wings and canard to 80% limit load would prove the airworthiness of the aircraft. In addition, a proof test of the control system to FAR 23 criteria is deemed necessary. The wing tip was also tested to 80% limit load.

6. Significant Actions: The following proof load tests were conducted (test data found in inclosure 1).

a. Wings and Canard: 4G's (80% limit load) positive.

b. Wings and Canard: 1G negative.

c. Aileron: 38 lbs. stick force to the right, then 40 lbs. stick force to the left on the pilot's stick. Then 40 lbs. on both pilot and co-pilot stick opposing each other.

d. Canard Elevators: 100 lbs. on the stick for elevator upward, then 100 lbs. downward; then 100 lbs. on both pilot and co-pilot stick opposing each other.

e. Rudder: 130 lbs. on each pedal to full travel (since LH/RH rudder work independently, pilots in opposition test is not necessary.)

DRDAV-DS
SUBJECT: Trip to AEFA, Edwards Air Force Base, CA, on 16 through 19 Jan 83

f. Wing Tip: 80% of the limit load moment applied was 125 lbs. at 42 inches from the root.

7. Summary:

a. A loud "creak" was heard during the 3rd application of shot bags on the canard. (This was approximately 60% of applied load.) Similiar smaller intensity "creaks" were heard as the loading progressed. A buckling of the fiberglass skin, backed by foam, was evident in the fairing of the nose section above the carry-through section of the canard, It is believed the bending of the canard compressed the foam section of the fairing causing the "creaks" and buckles. After the load was removed everything returned to normal and no permanent set was evident. The wing section loading was uneventful except for some very slight "creaking". When load was removed the wing section returned to normal with no evidence of permanent set. Control surfaces were operated while the aircraft was under load. An interference was found between the elevator torque-tube and an antenna wire. The wire was rerouted and the interference ceased. The canard was again loaded and the elevator operated without evidence of any interference.

b. The negative one "G" test was conducted without event. When the shot bags were removed, deflections returned to normal.

c. Travel of the canard elevators were measured, then the elevators clamped in the neutral position. Load was applied to the stick as specified. Measurements were then retaken, and indications are that no yielding of the control system components took place.

d. Travel of the ailerons were measured, ailerons clamped, and the stick loaded as specified; then travel remeasured. The measurement was eratic, and it was discovered the ailerons were misrigged causing then to hit a stop. After rerigging the procedure was repeated with excellent results, indicating no yielding in the system.

e. Both rudders were also misrigged, being unable to obtain full travel. After rerigging the rudders, full travel was measured on the left rudder, the rudder clamped in neutral and 130 lbs. applied to the foot pedal. The rudder was unclamped, and travel again measured. Test was repeated on right hand rudder. Neither rudder indicated any signs of permanent set in the system.

f. 125 lbs., which is 80% of the equivalent limit load moment was applied 42 inches from the wing tip, wing intersection. There was no defermation of either wing.

8. Recommendations: Recommend the aircraft be approved as airworthy from a structural point of view.

Robert Pieper
ROBERT PIEPER
Struc & Matls Div

Greg Kaprelian
GREG KAPRELIAN
Struc & Matls Div

1 Incl
as

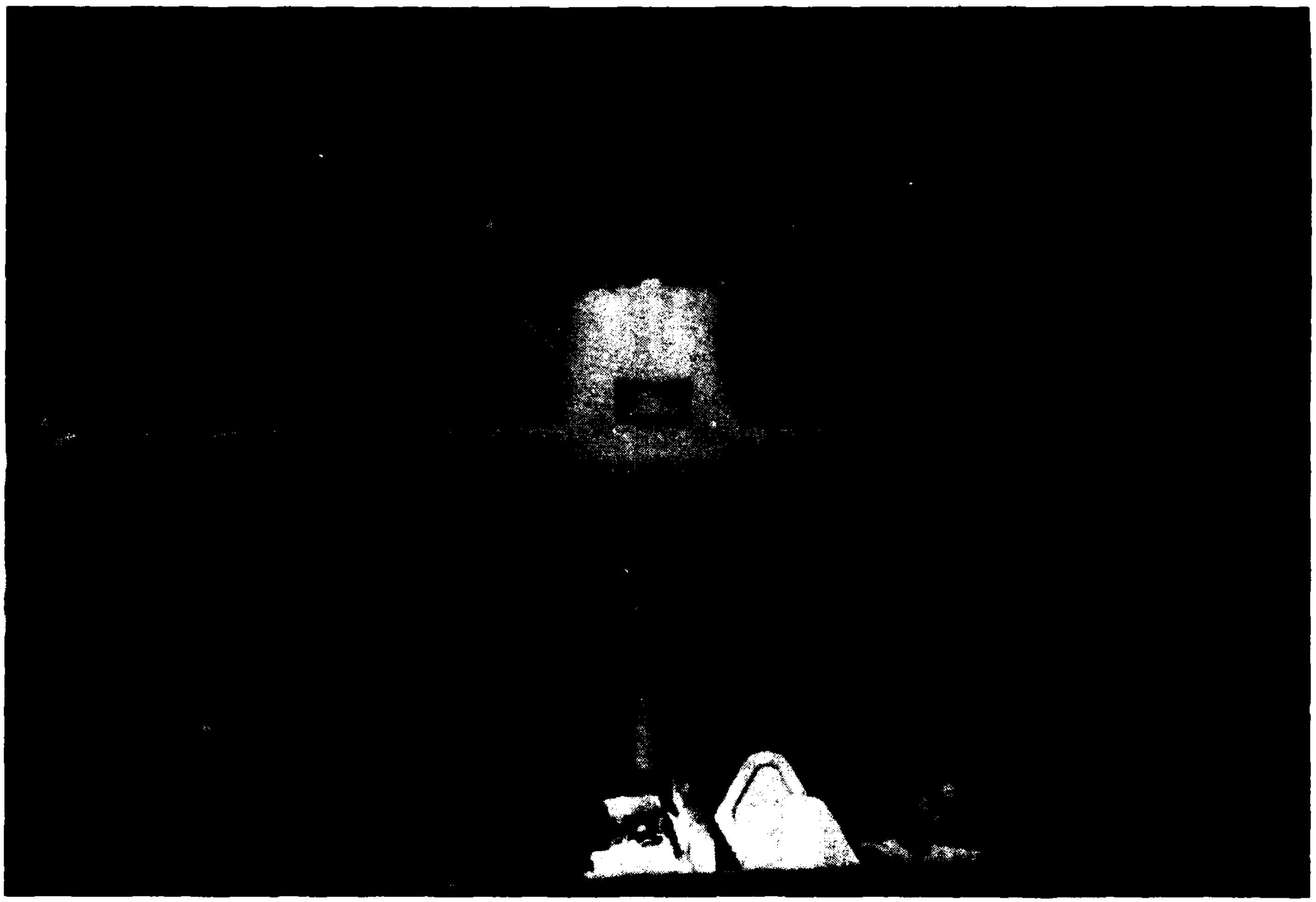


Figure 1. Set-Up: Positive Load Factor Tests (1G)

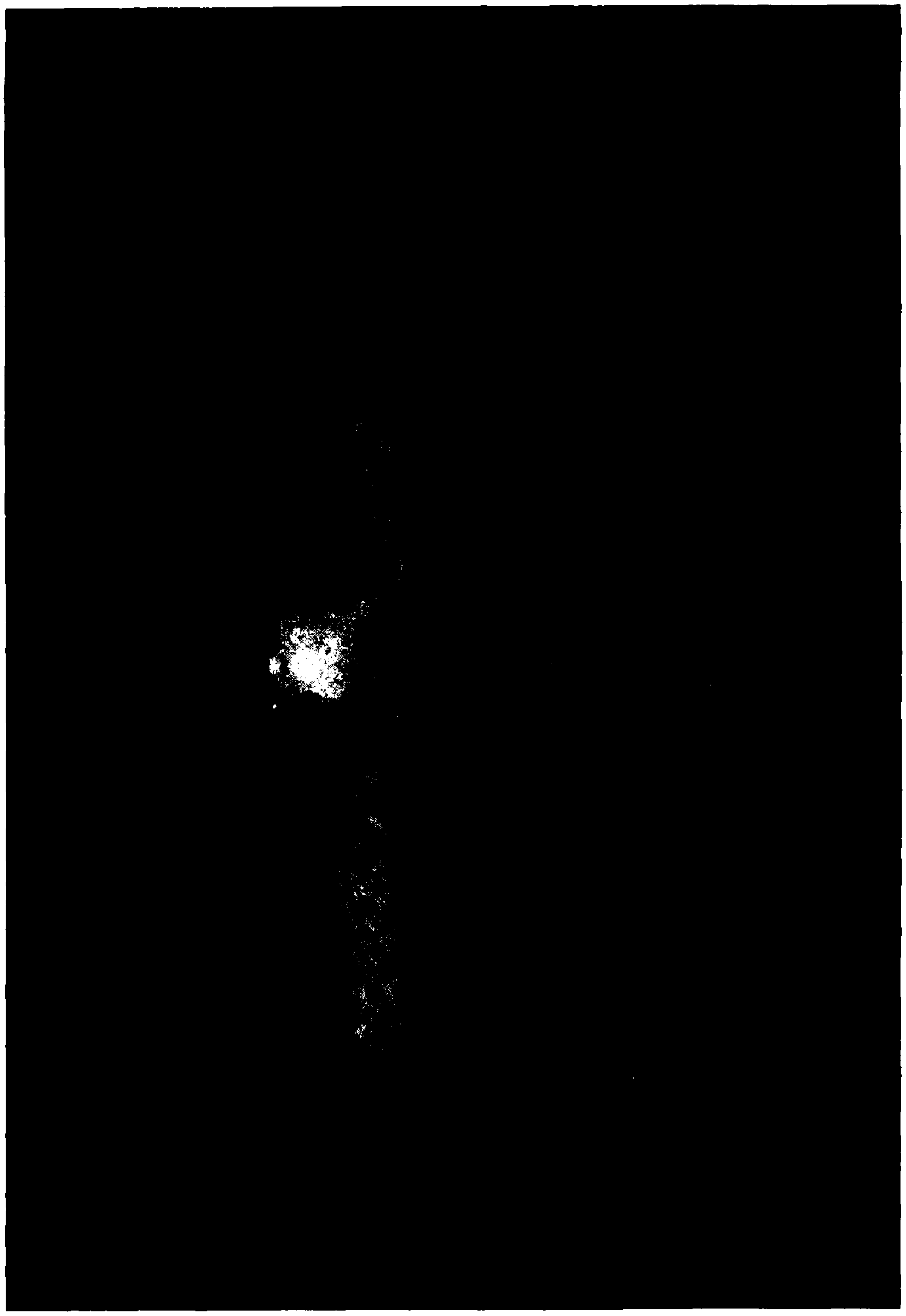


Figure 2. 4G Positive Load Factor Condition (Front View)

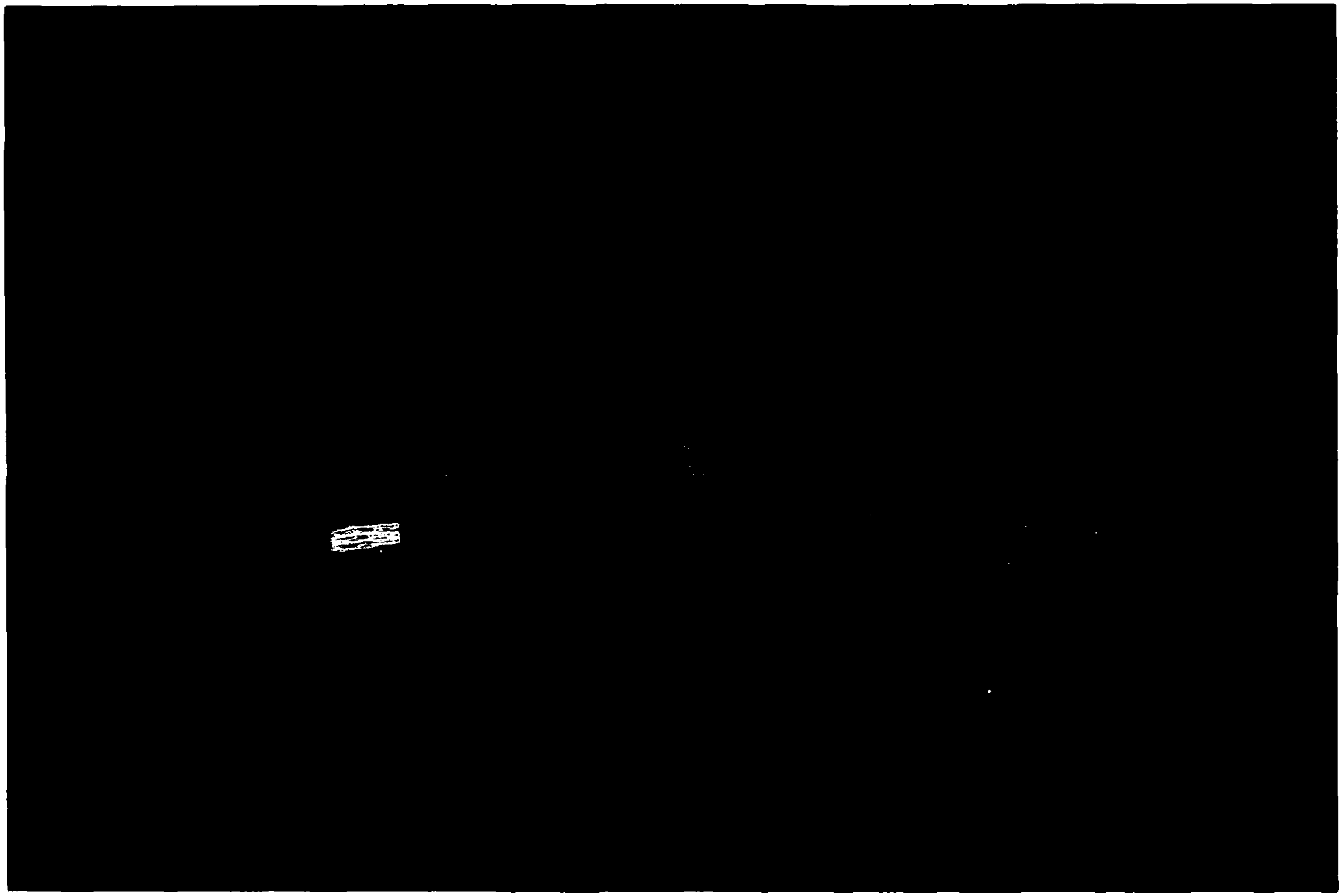


Figure 3. 4G Positive Load Factor Condition (Front View)

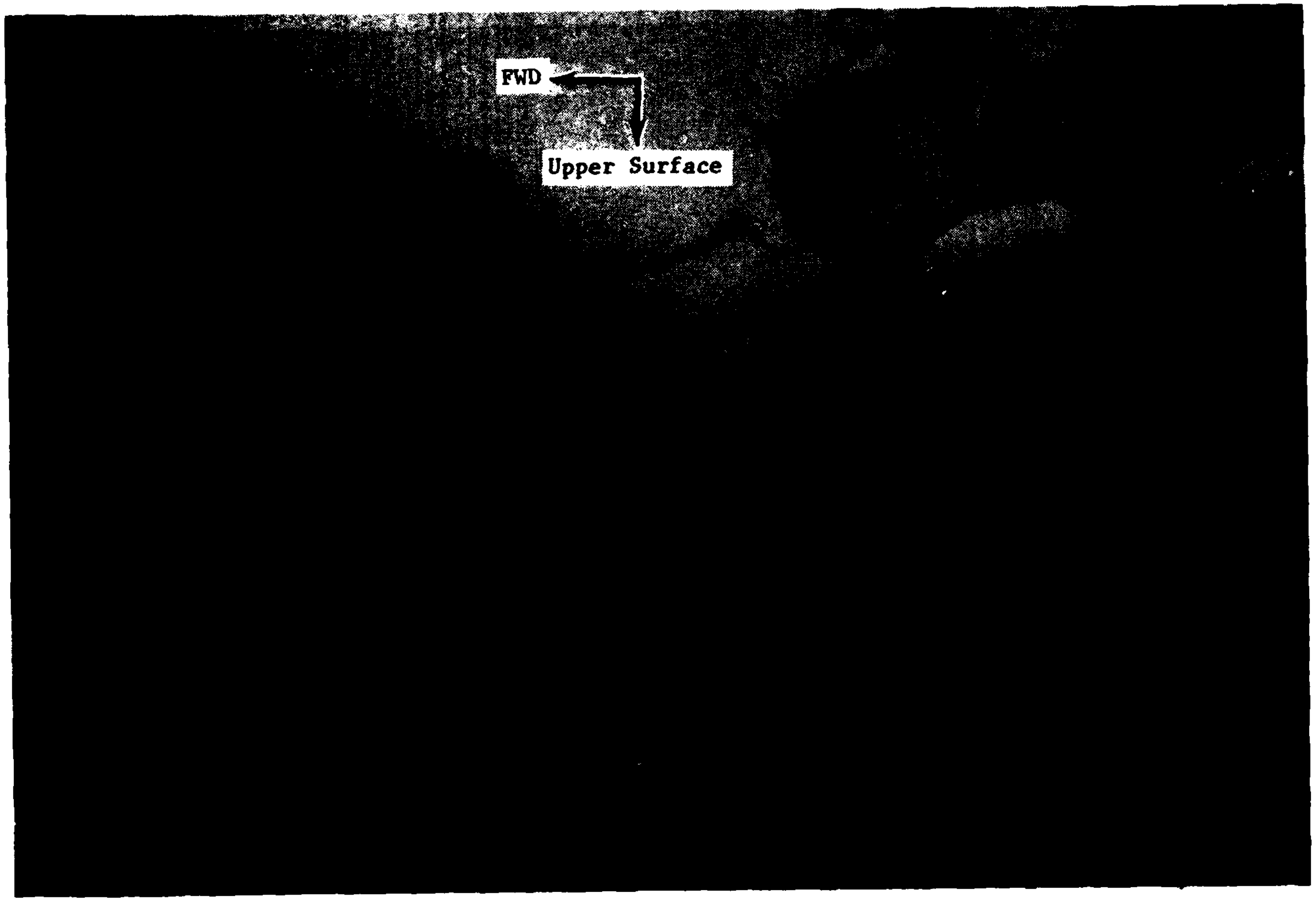
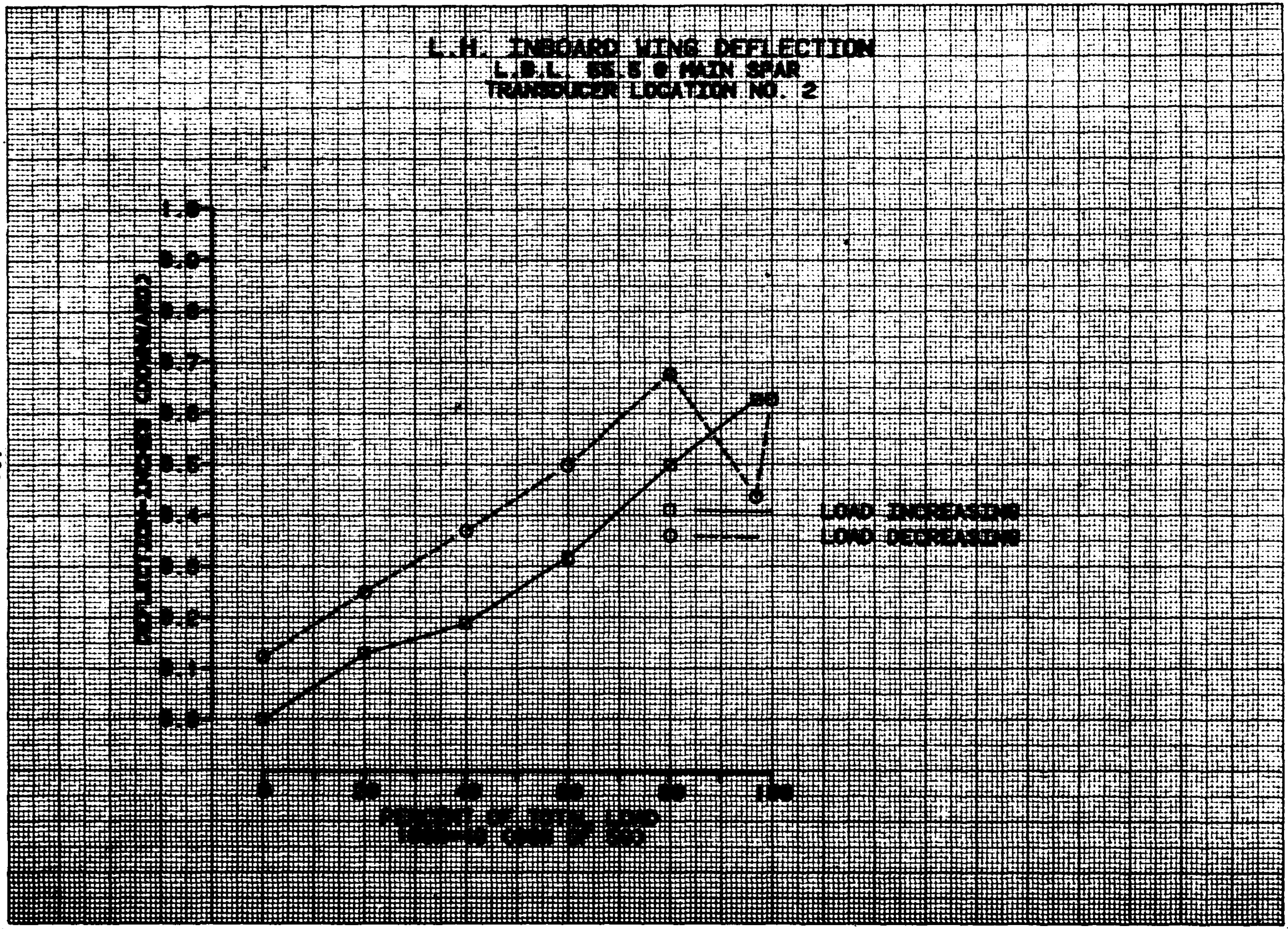
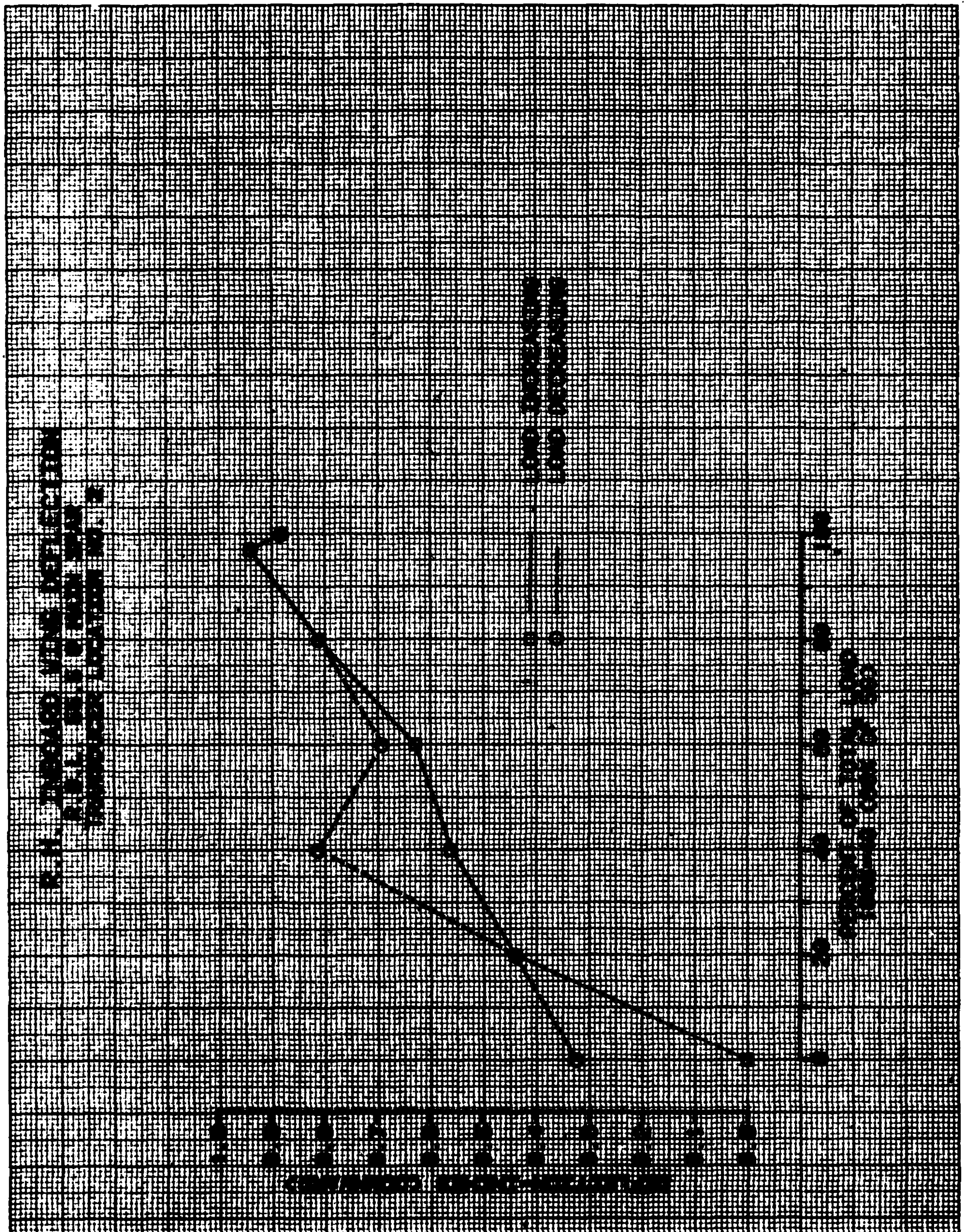


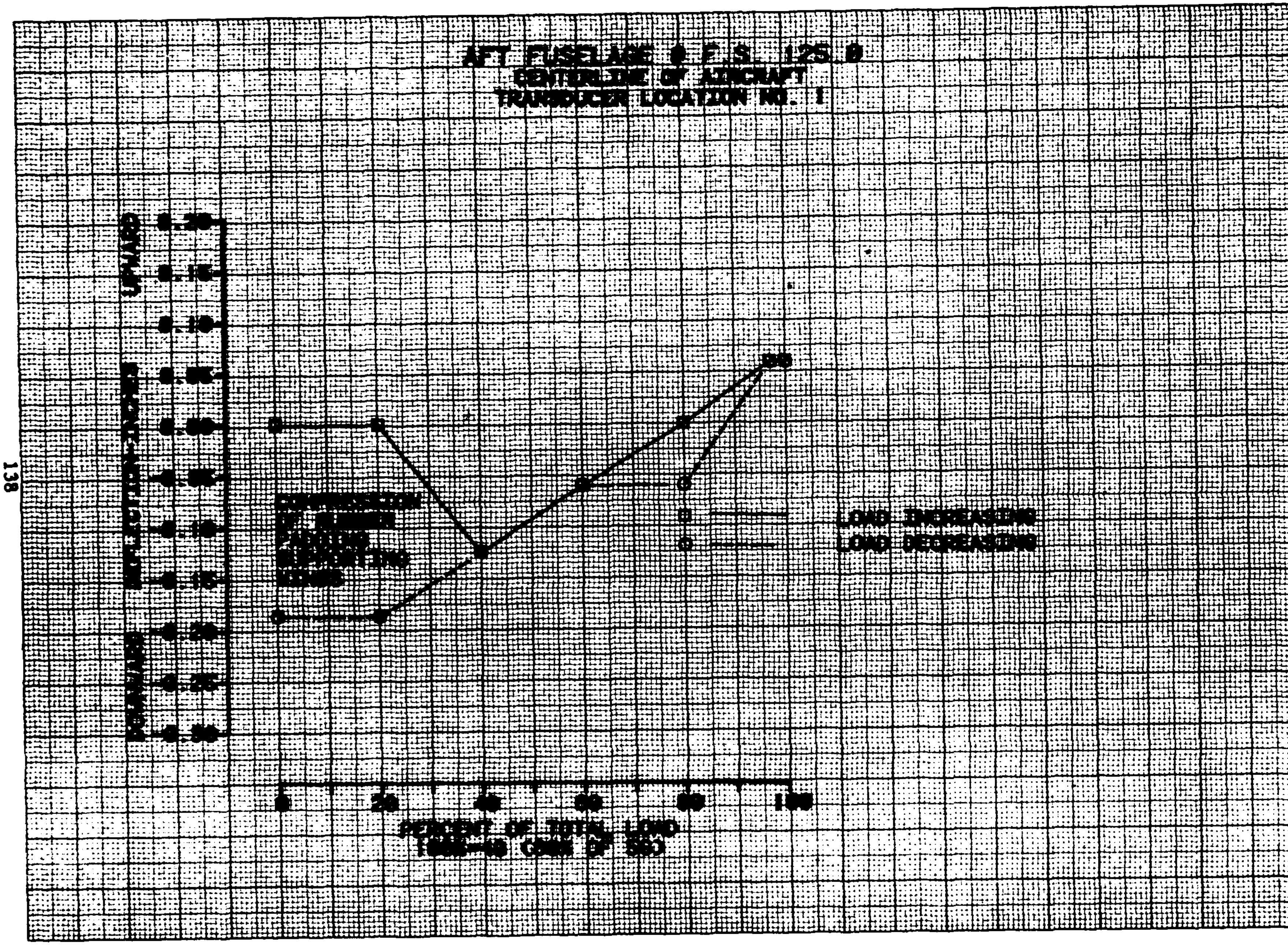
Figure 4. Non-Structural Buckling of Canard Fairing (4G)

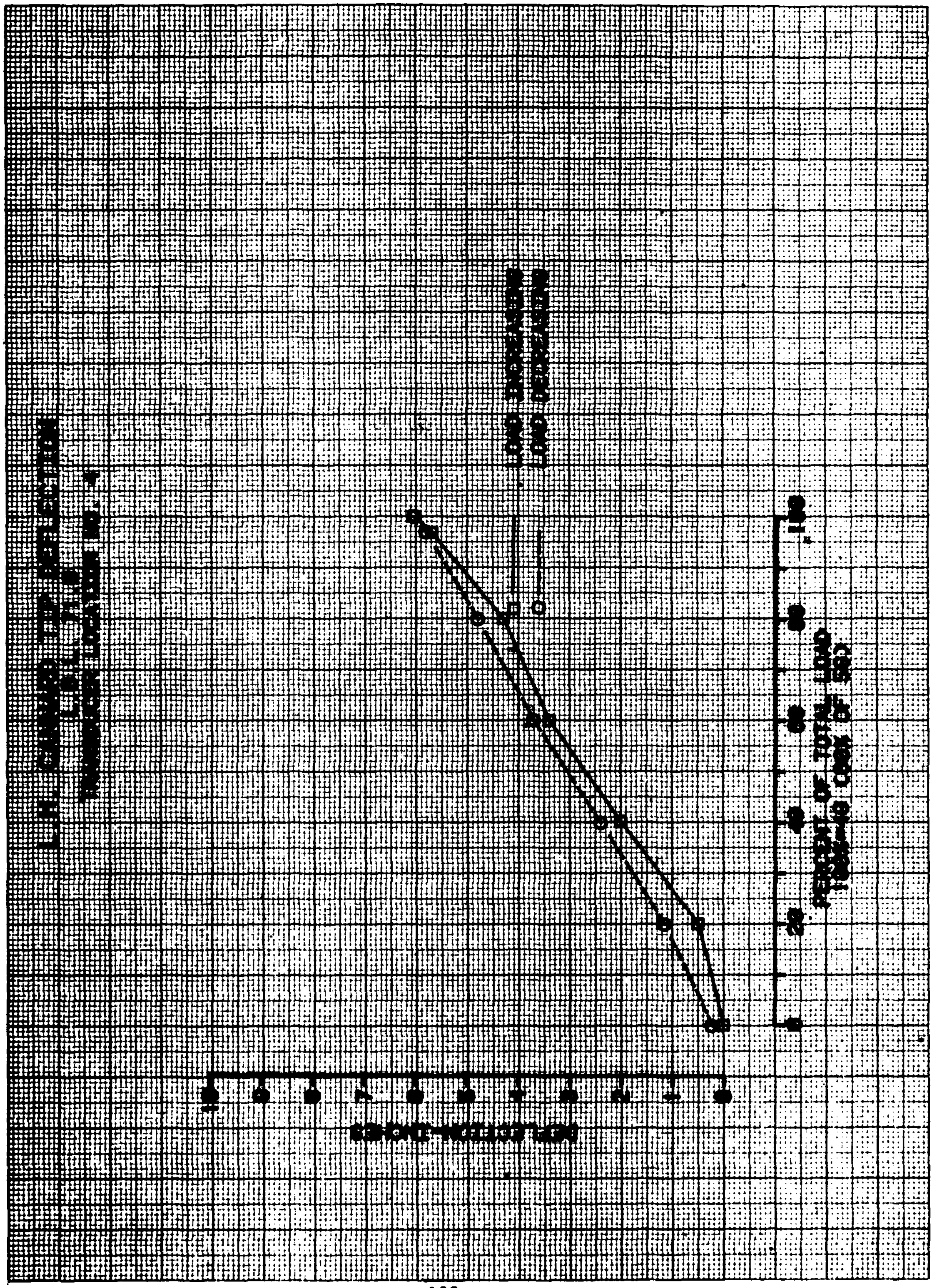
Figure 5. 2G Positive Load Factor Condition (Left Rear Quarter View)

Figure 6. 1G Negative Load Factor Condition (Front View)

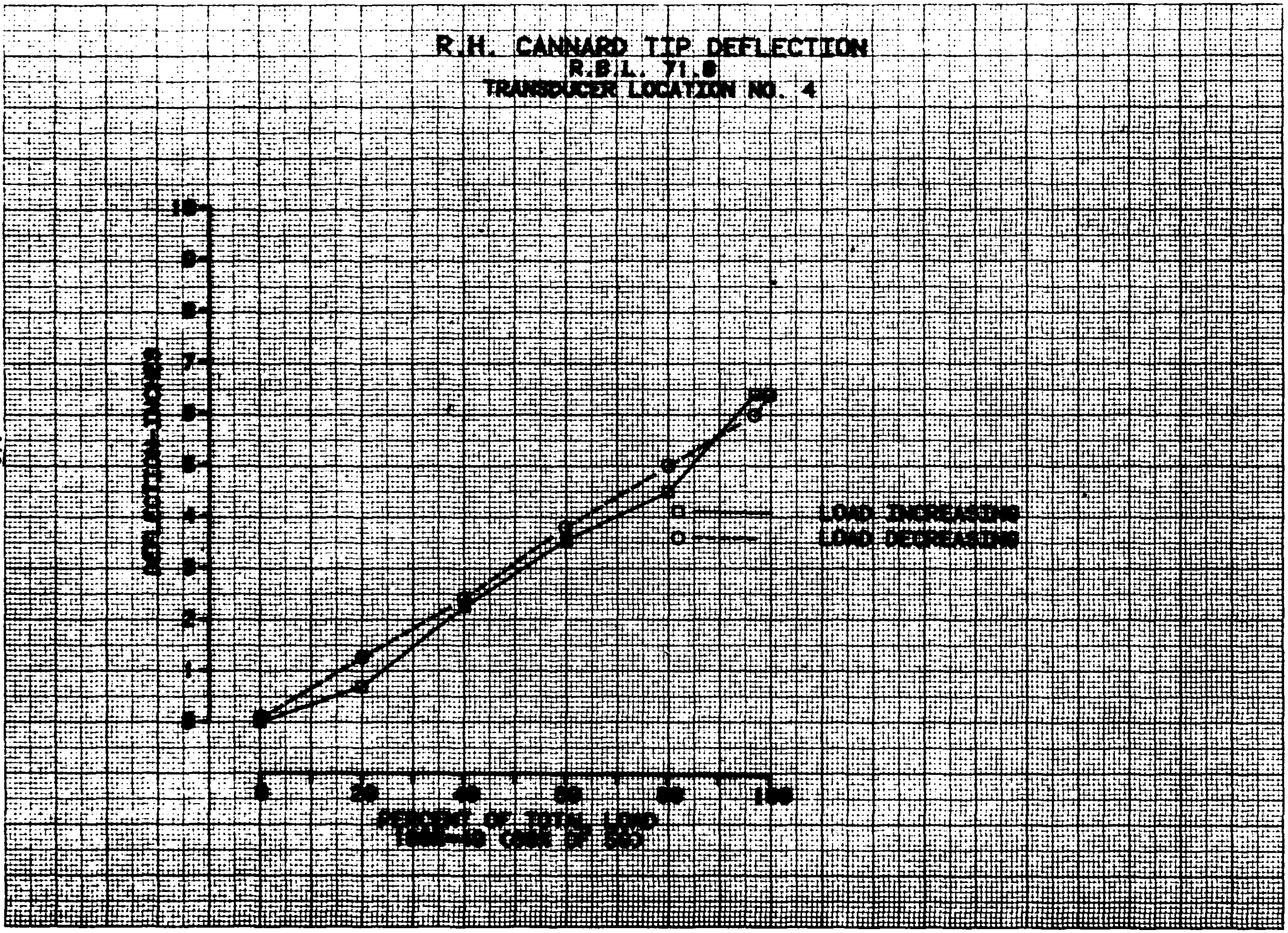

L.H. INBOARD WING DEFLECTION
TRANSDUCER LOCATION NO. 2
DEFLECTION-INCHES (DOWNWARD)
LOAD INCREASING
LOAD DECREASING

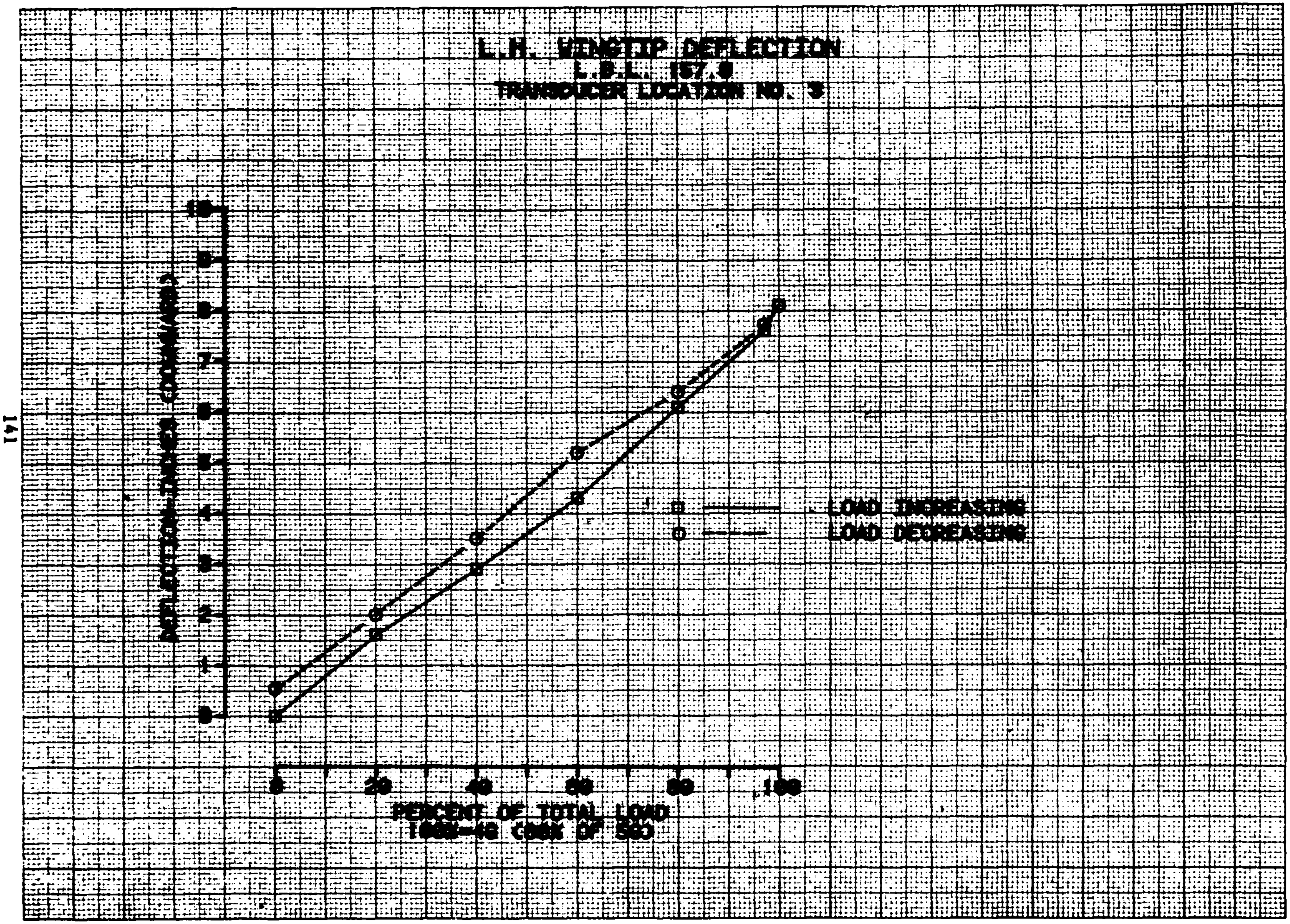

R.H. INBOARD WING DEFLECTION
LOAD INCREASING
LOAD DECREASING
0
20
40
60
80
100
PERCENT OF TOTAL LOAD

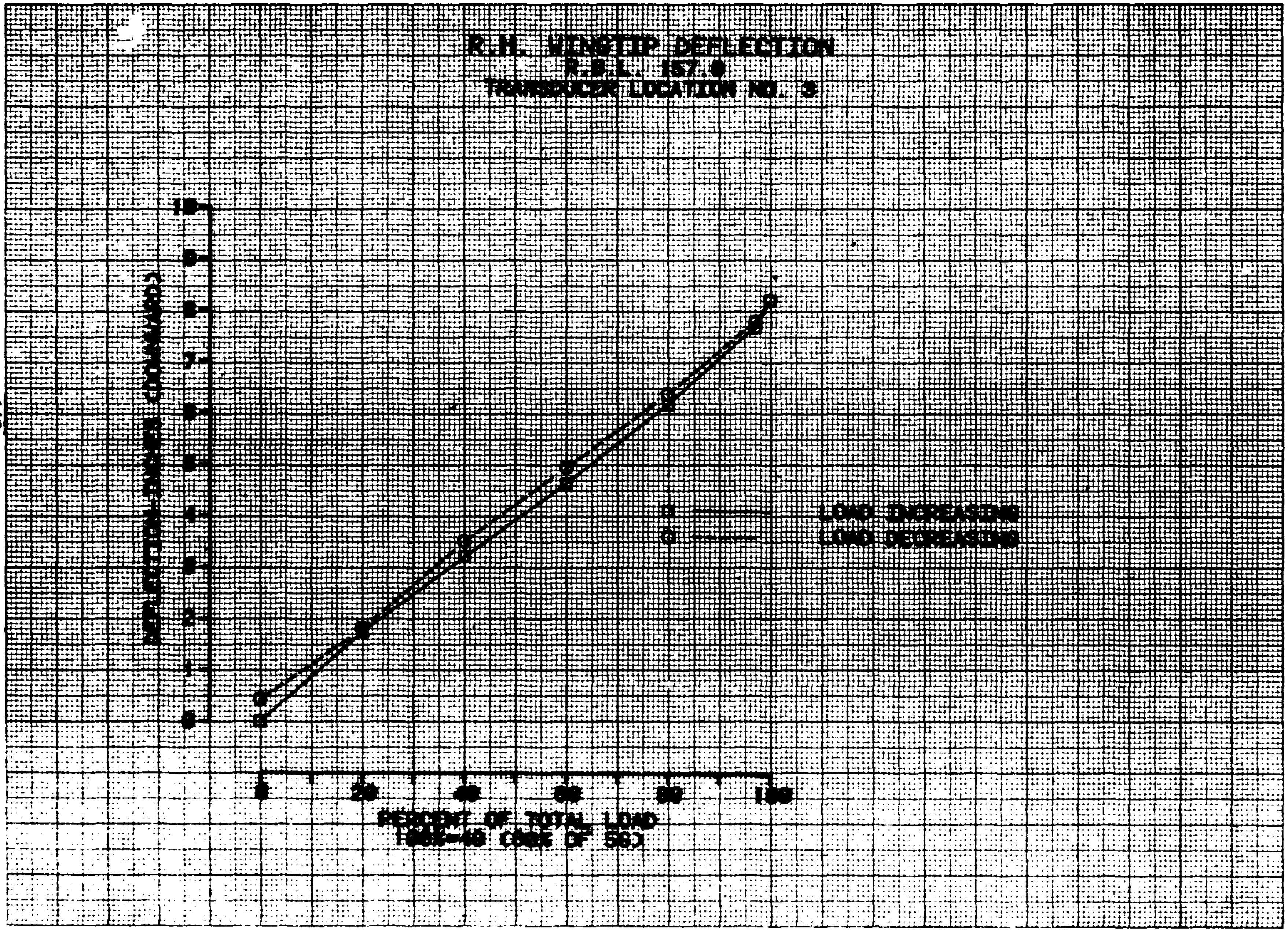

AFT FUSELAGE @ F.S. 125.0
CENTERLINE OF AIRCRAFT
TRANSDUCER LOCATION NO. 1
LOAD INCREASING
LOAD DECREASING
0
20
40
60
80
100
PERCENT OF TOTAL LOAD



L.H. CANARD TIP DEFLECTION
LOAD INCREASING
LOAD DECREASING
PERCENT OF TOTAL LOAD
DEFLECTION-INCHES


R.H. CANNARD TIP DEFLECTION
R.B.L. 71.8
TRANSDUCER LOCATION NO. 4
LOAD INCREASING
LOAD DECREASING
PERCENT OF TOTAL LOAD
0
20
40
60
80
100


L.H. WINGTIP DEFLECTION
TRANSDUCER LOCATION NO. 3
DEFLECTION-INCHES (DOWNWARD)
0
1
2
3
4
5
6
7
8
9
10
0
20
40
60
80
100
PERCENT OF TOTAL LOAD
LOAD INCREASING
LOAD DECREASING


R.H. WINGTIP DEFLECTION
R.B.L. 157.0
TRANSDUCER LOCATION NO. 3
LOAD INCREASING
LOAD DECREASING
0
1
2
3
4
5
6
7
8
9
10
0
20
40
60
80
100
PERCENT OF TOTAL LOAD
OF 5G)

APPENDIX G. DYNAMIC AEROELASTIC TEST

A limited shake test was conducted on the Rutan Long EZ fixed wing two place aircraft at NASA-Dryden in cooperation with AEFA on 20 and 21 Jan 1983 to determine some of the low frequency resonant modes of the wings and canards.

The aft control stick was rigidly restrained to hold the elevators and ailerons in the neutral position. The aircraft was empty of fuel on its tricycle landing gear with tire pressures reduced to approximately 50% normal. Shot bags were placed in the seat locations representing the weight of fuel and pilots. Shot bags were also placed against the wheels to restrain rigid body motion. The NASA facility had two fifty pound electromagnetic shakers (armature weight approx 0.6 pounds) a force gauge and four accelerometers along with associated charge amplifiers, signal conditioners, tracking filter, and an eight channel time history pen recorder.

The NASA adhesive tape used to attach the shakers to the aircraft failed often and was also impractical for use with a roving accelerometer but was very good for fixed accelerometers. Some old dried bees wax was used with the roving accelerometers.

Several sinusoidal frequency sweeps between 4 and 50 HZ were applied to the aircraft. The shaker force was measured by the force link and its output along with that from the fixed accelerometers were measured by the traces on the eight channel time history recorder. The shaker force found reasonable to excit this aircraft was less than 3 pounds. Variations were made of the locations and phasing (in or out of phase) of shakers and the locations of the fixed accelerometers. Approximate resonances of the primary aero surfaces (wings and canards) were determined from the larger magnitudes of the traces on the recorder. Rotation frequencies of the ailerons and elevators were not determined because these values were too highly affected by free play and the force and excursion of rotation.

To help confirm the predominant resonant modes, the aircraft was vibrated at frequencies selected from the resonant search sweeps and mode shapes determined from recordings of the output from the accelerometers, two of which were moved to different locations on the wings and canards.

The table below summarizes the resonant frequencies and the component predominant mode associated with that frequency.

Mode	Wings	
1	Symmetric First Bending	5.6 HZ
2	Antisymmetric First Bending/Torsion	9.9
3	Antisymmetric First Torsion	14.1

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Mode	Canard	
4	Symmetric First Bending	12.0 HZ

Mode	Winglet Root Bending	
5	Symmetric	31.0 HZ
6	Antisymmetric	25.8

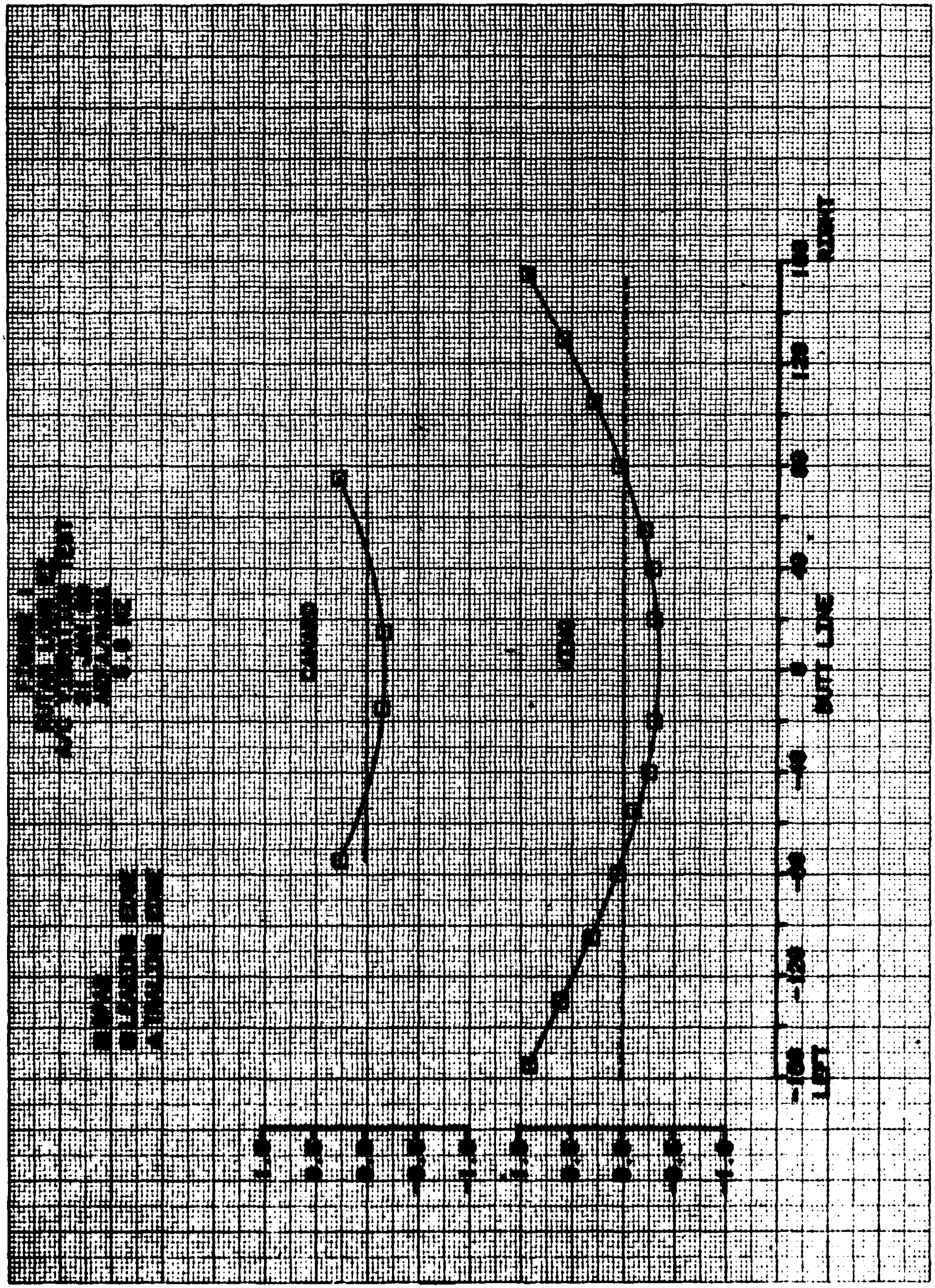
Plots of Modes 1, 2, and 3 are presented as Figures 1, 2, and 3.

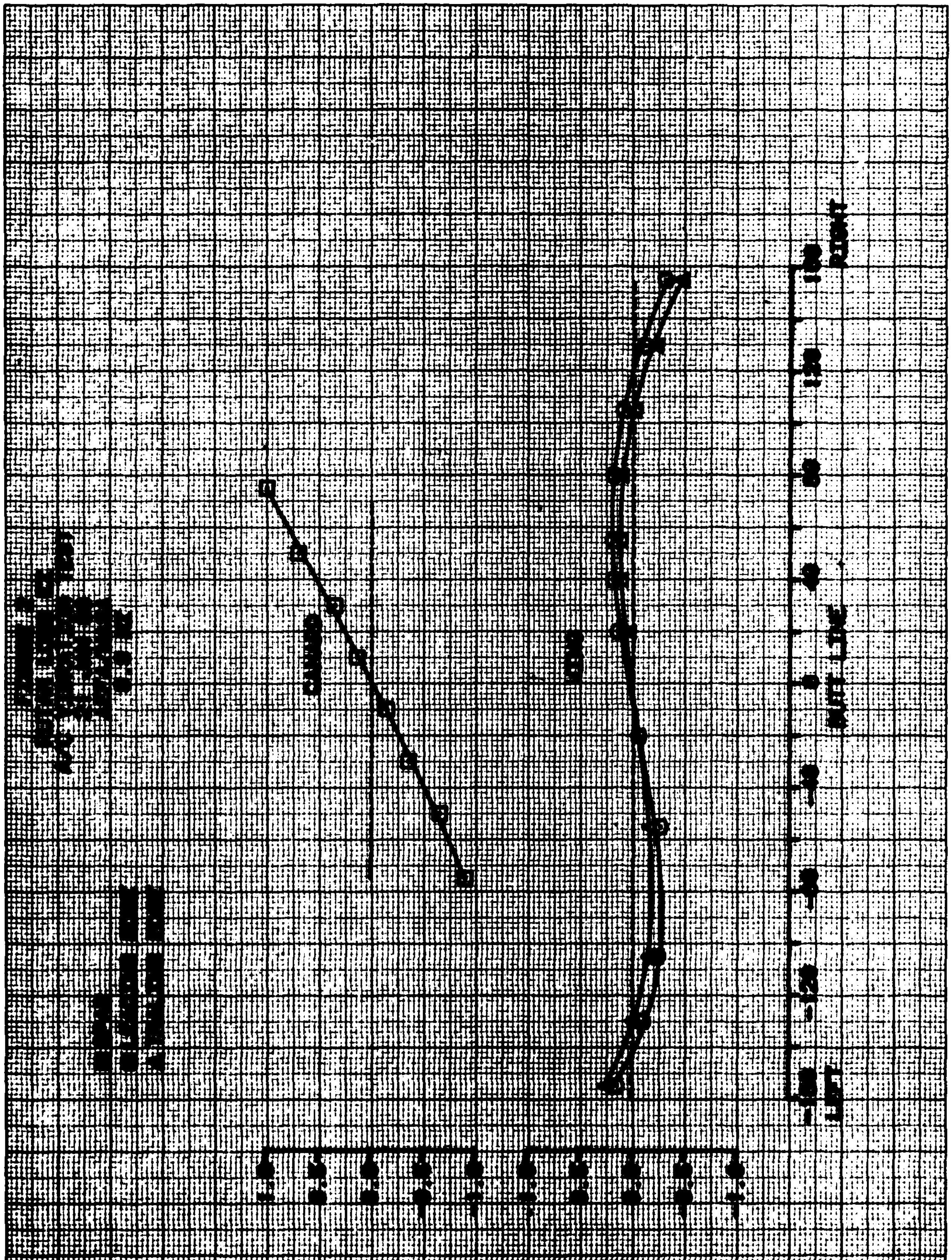
These mode shapes show that the left and right sides of the aircraft were constructed in such a manner that the structural, mass and elastic distributions are similar with no significant stiffness discontinuities.

William W. Hamilton

WILLIAM W. HAMILTON

DRDAV-DA


CANARD
BUTT LINE
LEFT
RIGHT



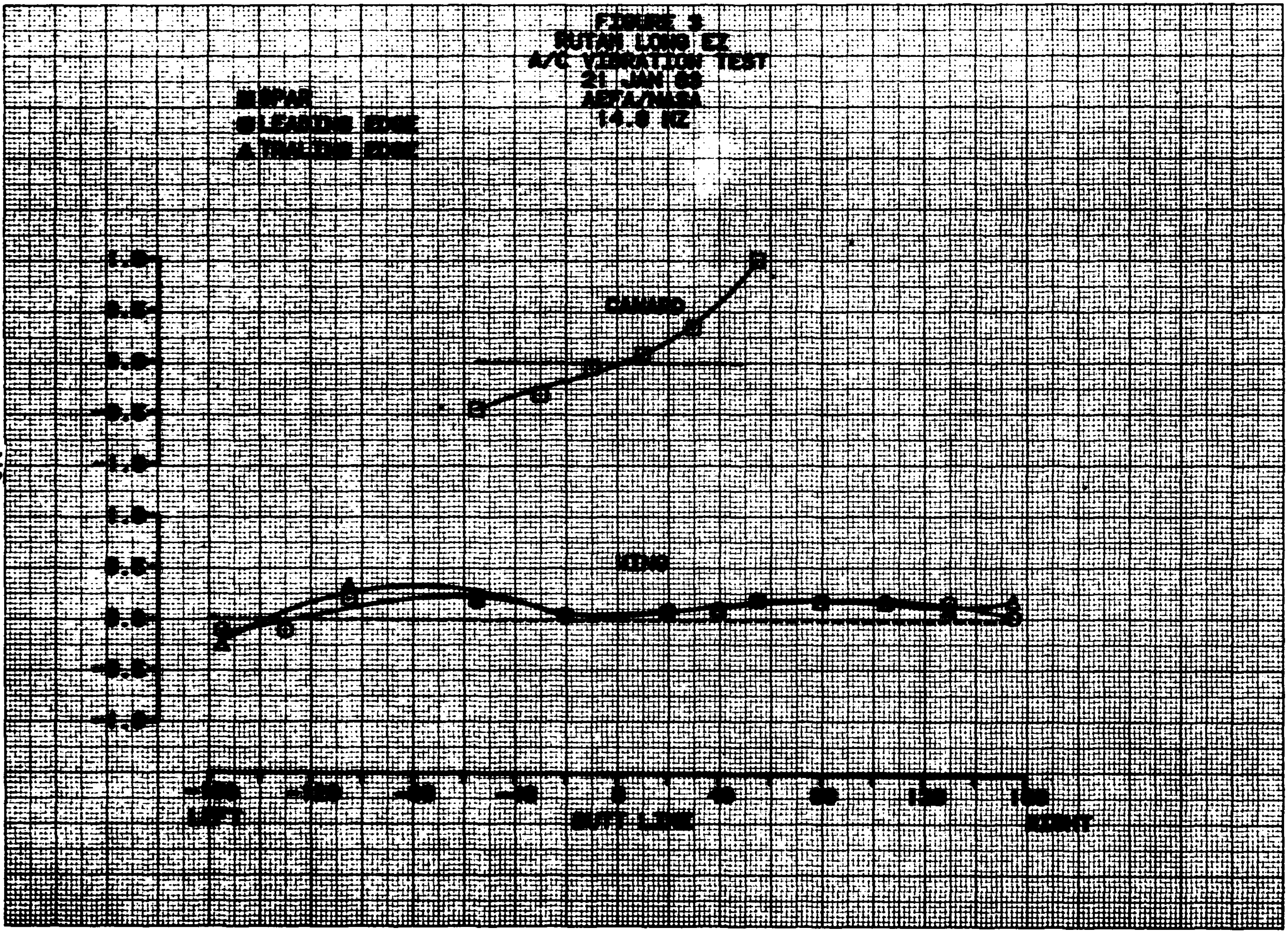


FIGURE 3
RUTAN LONG EZ
A/C VIBRATION TEST
SPAR
LEADING EDGE
TRAILING EDGE
CANARD
WING
BUTT LINE
LEFT
RIGHT

APPENDIX H. DEFINITIONS, ABBREVIATIONS, AND SYMBOLS

This list includes most of the symbols used in this report. However, certain portions of the report use special or unusual abbreviations and symbols. The meaning of these is made clear in the text of the report and, when that is the case, the abbreviation or symbol will not be found in this list. Also, certain symbols have more than one meaning; however, the context should make the meaning clear.

Symbols and Abbreviations	Definitions	Unit
AN	Army/Navy	--
ANA	Air Force Navy Aeronautical	--
ANS	Army/Navy Standard	--
AC	Alternating current	--
b	Wing span	feet
C_{Do}	Minimum coefficient of dray of the propeller-feathered drag polar	--
C_D	Coefficient of drag	--
$C_{D_{BL}}$	Base-line coefficient of drag	--
$C_{D_{PF}}$	Powered flight coefficient of drag	--
C_P	Coefficient of power	--
C_L	Coefficient of lift	--
Cont	Continuous	--
D	Drag	--
De	Degree	°C
e	Oswald's span efficiency factor	--
f	Equivalent flat plate area	ft^2
F_N	Jet thrust	pounds
g	Acceleration of gravity	ft/sec^2
H_D	Density altitude	feet

Symbols and Abbreviations	Definitions	Unit
H_{p_i}	Indicated pressure altitude	feet
H_p	Pressure altitude	feet
$H_{p_{ic}}$	Instrument corrected pressure altitude	feet
J	Advance ratio	--
L	Lift	pounds
MAC	Mean aerodynamic chord	--
Max	Maximum	--
MCP	Maximum continuous power	--
Min	Minimum, minute	--
N_p	Propeller speed	rpm
NAMPP	nautical air miles per pound of fuel	--
NU	Nose up	--
ND	Nose down	--
OAT	Outside air temperature	°C
p	Roll rate	radians/sec
P_a	Ambient pressure	in. of mercury
P_o	Standard-day, sea level pressure	in. of mercury
Psi	Pounds per square inch	$lb/in.^2$
q	Dynamic pressure	lb/ft^2
Q	Torque	ft-lb
ref	Referred, reference	--
R/C	Rate of climb	ft/min

Symbols and Abbreviations	Definitions	Unit
S	Wing area	ft^2
SHP	Shaft horsepower	--
$SHP/\delta\sqrt{\theta}$	Referred shaft horsepower	--
SL	Sea level	--
S/N	Serial number	--
STD	Standard	--
T_a	Ambient air temperature	°C
T_C'	Coefficient of thrust	--
T_i	Indicated air temperature	°C
T	Thrust	lb
T_{ie}	Instrument corrected on temperature	°C
THP	Thrust horsepower	HP
T_o	Sea-level, standard-day static temperature	°K
V_{cal}	Calibrated airspeed	knot
VHF	Very high frequency	--
V_i	Indicated airspeed	knot
V_{ic}	Instrument corrected airspeed	knot
V_T	True airspeed	knot
V_{MC}	Airspeed for minimum control	knot
V_S	Stall airspeed	knot
V_H	Maximum airspeed for level flight	knot
V_{MO}	Maximum operating airspeed	knot
V	True airspeed	ft/sec

Symbols and Abbreviations	Definitions	Unit
W_a	Engine airflow	lb/hr
W	Weight	pounds
°C	Degrees Centigrade	degrees
°F	Degrees Fahrenheit	degrees
°K	Degrees Kelvin	degrees
Δ	Difference	--
$\Delta C_{D_{PF-BL}}$	Difference in coefficient of drag due to thrust effect	--
ΔV_{PC}	Airspeed position error correction	--
ζ	Damping ratio	--
θ	Temperature ratio, descent angle	degrees
δ	Pressure ratio	--
σ	Density ratio	--
ρ	Air mass density	slug/sec^3
ω_d	Damped natural frequency	radians/sec
ω_n	Undamped natural frequency	radians/sec
a	Angle of attack	degrees
ϕ	Roll of bank angle	degrees
η_p	Propeller efficiency	--
ϕ/β	Roll-to-yaw ratio	--
dh/dt	Tapeline rate of descent	ft/min
π	3.14159	--
$\eta_{in.}$	Inlet duet efficiency	percent

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